Electrochemical and Metallurgical Industry

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Electrochemical and Metallurgical Industry

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The Outlook.

When exact statistical data on the production of the metallurgical and chemical industries in 1905 are available, the claim that the past year has been a red-letter year in the industrial almanac of this country will undoubtedly be found justified. To mention only an instance, the market for metals has been very high and is very high now, while this note is being written—a most remarkable phenomenon for the week after Christmas. What is more important, however, prosperity has been coupled with progressiveness towards new developments, and since prosperity is Nature's acknowledgement of activity in the past, we may hopefully look into the future. The specific American trait of working on a large scale and of pushing the output to the utmost limit, has been manifest during the past year in every direction. We cite as examples the reverberatory and the blast furnaces of enormous tonnage at Anaconda, as well as the fact that the output of our electrolytic copper refineries is now twice what it was six years ago. But besides this tendency of working on a large scale, there has been a manifest desire to improve methods. This has not always been so. Huge scale working tends towards standardization, and means the investment of large amounts of money in installations. It is most gratifying to see that in spite of this fact our industries are endeavoring to adapt their equipment and methods to the progress of the art. The Carnegie Steel Co. will equip its new furnaces with Mr. Gayley's dry-blast system. Several large blast furnace plants of the United States Steel Corporation will put in large gas engines, operated by blast furnace gases, for the development of electric power. By-product coke ovens are growing in favor. In the lead industry the adoption of the Huntington-Heberlein process has been the most important development of the last year, while Mr. Betts' electrolytic lead refining process has achieved international importance through the erection of English works. In the special field of elctrochemistry the first days of the new year will witness the opening of the new chlorine-alkali works, using the Townsend process, and of the Acheson siloxicon works at Niagara Falls, as well as the starting of the 80-ton electric Héroult furnace at the Halcomb crucible steel works. These are only a few examples which could be easily multiplied. They indicate a new life and a new spirit in the industrial and metallurgical industries of this country.

Separation of Copper and Nickel

The treatment of the nickel-copper ores of the Sudbury district is a problem of the greatest importance for the nickel industry. Roasting and smelting, followed by converter treatment, yields a high-grade nickel-copper matte, and the problem is to separate the nickel from the copper. This is being done on a very large scale by the Orford process, at the works

of the Orford Copper Co., in Bayonne, N. J. The principle is to subject the molten matte to contact with sodium sulphide, whereby the heavier nickel sulphide separates by gravity from the copper and iron sulphides. The process is cheap and has been very successful from a commercial standpoint. Its greatest drawback is that the separation is not sharp, that the resulting nickel is impure. To get pure nickel, electrolytic methods early suggested themselves, on account of the analogy with copper refining. For a complete understanding, however, it is not sufficient to look at the engineering side of the problem, but the commercial situation must also be considered.

* * *

Before the International Nickel Co.—the "Trust"—was formed, it was in the interest of independence that the Canadian Copper Co., in Copper Cliff, endeavored to develop a process different from the Orford process. For a series of years experiments went on to devise an electrolytic method. An unsuccessful experimental trial was first made with the process of the late C. Hoepfner, but success was obtained later with the electrolytic process of the chief chemist of the Canadian Copper Co., D. H. Browne. At the same time the Orford Copper Co., while using the alkaline sulphide smelting process on a large scale, was compelled, for a number of years, to meet the demand for very pure nickel for certain purposes by having a portion of its nickel product refined at the Balbach works in Newark, by the electrolytic process of their chief engineer, William Thum. Later came the consolidation of the different nickel companies in one trust, which then controlled both the Orford Copper Co. and the Canadian Copper Co., and the Browne process was given up for the time being, since its cost was found to be higher than that of the Orford process. A large item in the cost sheet of the Browne process is the cost of electrical power, and it is expected that when the electric transmission plant to the Copper Cliff works of the Canadian Copper Co. will be completed, cheap electric power will be available, and the prospects for the Browne process will be greatly improved. In the meantime considerable experimental work has been done at the Bayonne works of the Orford Copper Co. According to a note mentioned in the Synopsis of our present issue, electrolytic nickel refining (starting evidently with the impure product of the Orford process) is now carried out on a small scale at the Orford works. Concerning the experiments made on electrolytic copper-nickel matte treatment at the same works complete secrecy has been maintained. Information on one process, worked out there by N. V. Hybinette, is, however, now available from a patent recently issued, and discussed in the department on Recent Metallurgical Patents in our present issue.

* * *

It is interesting to compare in a general way the Browne process and the Hybinette process. Browne (whose process was described in detail in our issue of July, 1903,) uses a chloride solution, Hybinette a sulphate solution (with a weak acid). Both inventors use a cyclic process, and both pay special attention to the important problem of keeping their solutions pure. In the Browne process it is chlorine, which goes through a cyclic process, in the Hybinette process it is the nickel sulphate electrolyte. Browne deposits by far the largest part of the copper and all the nickel electrolytically, and removes the rest of the copper and the iron by chemical means. Hybinette deposits only the nickel by electrolysis, while the copper is precipitated by cementation. Browne uses simple electrolytic cells, Hybinette a diaphragm cell of novel construction. It was recently stated that the Hybinette process is to be tried outside of the nickel trust, at Sault Ste Marie. The results will be watched with interest.

Depreciation Due to Advance in the State of the Art.

Our friends and co-workers, the electrical engineers, have made use of the phrase, "depreciation due to the advance in the art," in their methods of accounting, and especially in the accounting arising from law suits. There is a very good reason for this in the electrical profession, and that is that the marvelous application of fixed mathematical laws by a brilliant coterie of engineers has resulted in changes proceeding at the rate of an express train. Good, excellent generating machinery of twelve years ago is now antiquated for a large central station, because it is brought into competition, for instance, with the high-speed alternating-current turbo-generator, and it is not impossible that the advent of the osmium and tantalum lamps and of the graphitized filament may place many a small lamp plant in uncomfortable circumstances. In applied chemistry—or as we like to term it, applied physical chemistry—such changes have not been so marked as in electrical engineering. The reason for this is plain. Progress is made in metallurgy and chemical engineering more by the methods of "cut and try" than by rigid theoretical deduction. Metallurgical experimenting is costly and slow—slow, very slow. Many processes successful in the laboratory are abject failures in the works, because of faulty engineering, or more often, because of ignorance of the real conditions for success. Perfect theory would, of course, have rendered all easy.

* * *

However, there have been many changes in metallurgy, such as the Bessemer process, which restricted the advance of the puddling furnace. The basic steel processes which destroyed natural monopolistic value of the "Bessemer ores," the cyanide gold process, which rendered low-grade gold mines available, are both instances of epoch making changes. The electrolytic copper process not only made high conductivity copper commercially available, but opened up vast mines of Montana and Arizona. All these changes, however, were slow working, because of the great "economic friction" in metallurgy, which is an art rather than a department of applied science. However, due to the great progress made in physical chemistry and the general and widespread propagation of its tenets at the present, metallurgy is gradually coming to the same state, which is typical of electrical engineering.

* * *

No conservative system of accounting has been devised to cover this all-pregnant phrase, "depreciation due to the advance in the state of the art." The nitre beds of Chili have an enormous value now. But when the electrochemical fixation of nitrogen from the air is a demonstrated success, perhaps this value will be annihilated over night. The Huntington-Heberlein roasting process will wipe off the book value of

thousands of dollars of capital tied up in hand roasters. The electric steel furnace will do the same for the present inefficient crucible steel furnace. Then, too, the advance of analytical chemical methods and their widespread diffusion will obliterate the fictitious value of many "brands" whose "good will" has largely a sentimental worth only. There is just one way for the enterprising manufacturing company to succeed and discount this uncertain but sure depreciation. Adopt the methods used by many, but most of all by that canny American, Andrew Carnegie, and make your plant the most modern and efficient in the world, by the aid of able and enthusiastic partners. Raise the personal equation to the highest power. There the depreciation will be written off on the capital account of your competitor's book and not on your books. In this twentieth century, modern business methods are the only right ones.

"When all Treasures are Tried, Truth is the Best."

We hesitate to approach the subject of "graft" in business and politics, when the editorial page of every journal of the country is replete with similar warnings and forbodings. But the question is so germane to engineering and the great flood of prosperity that is blessing our land is so intimately connected with it, that we feel that there is little apology needed for considering the basic causes of what we may term "commercial leprosy." Anthropologists tell us that human nature has changed but little in 2,000 years, and it is well to confess this. Then we can trace the causes directly to the changing environment and sociological conditions of the twentieth century. There is much truth in the song of the Broadway theatre ending with the refrain, "In the good old days of old when people did just as they ought to do—or at least they never told." In these days of "modern inconveniences," the limelight of the daffodil-colored press, by aid of photograph, telegraph and telephone, brings out every bit of scandal into bold relief. Not that we did not have public scandals, as the "Credit Mobilier" in the seventies, nor that other countries did not have them, as France in the "Little Napoleon's" reign, England in the time of Clive, or Prussia in the days of Frederick the Great. But modern-applied science has developed the means of bringing many a nastiness to the public vision.

* * *

Aside from the part played by applied science in showing up dishonesty, we believe that to her door can be traced the fundamental causes of dishonesty. These causes are two in number, one intellectual and moral, the other material and sociological. Galileo, Copernicus, Newton, Darwin and a host of other scientists have brought forth fundamental truths of nature that are seemingly at variance with the doctrines of the church. To a thinking and logical man, the tenets of the ecclesiasticism are but the forms of an outgrown creed, and no set philosophy has arisen to take the place of old faith. True, every thinking man rejecting the forms of theology, finds out by his thirtieth year a working moral code. But, nevertheless, in his formative young manhood he is subjected to the moral strains that often reduce a thinking Puritan to cold-blooded materialism. The second cause, the material one, is due to great increase in material wealth brought about by inventions —especially metallurgical inventions. For instance, Sir Henry Bessemer's process of making steel rails at a low cost, connected the broad acres of the West in circuit with the entire commercial world. And as cheap metals are the fundamental necessities of all mechanical arts, we can truthfully say that the application of the chemistry of Dalton and Lavoisier has been the prime cause of this excess of material wealth. The extravagance of the princes of fortune has caused moral deterioration of the less fortunate. Concisely stated, the increase of national wealth has subjected our national conscience to a strain nearly up to its elastic limit. Individuals see fortunes made by luck on good management, and these are the desire of the jealous and covetous. Integrate this covetousness between national limits and you have "graft."

* * *

Three young boys once used to gather mushrooms together, and being straight, nice, honest boys, they made an agreement, let us call it a "gentleman's agreement." This was to the effect that he who first "sighted" a "big bunch" had all in the vicinity of 10 feet of the biggest mushrooms. This scheme worked beautifully, and much pocket money was gained by selling the product of their gleanings at 75 cents a pound. But one Saturday, having walked long, they came to a virgin pasture where the mushrooms were so thick that there was there at least $15 for each. Then the rule which worked so well in the lean fields was slightly transgressed by one enthusiastic youth. This lead to a second infraction. Retaliation, recrimination and bickering ensued in quick succession; then a fight—*bellum omnium contra omnes.* Finally, disgusted and sorrowful, for fully half of their mushrooms were destroyed, these little fellows put all their mushrooms in a pool and divided them equally. It seems to us that this story is illustrative of the sociological changes that are being enacted before our very eyes; that our great increase of material wealth has blinded our eyes to justice, and that a mad race for wealth at any price has followed. Whether we will have the recourse to socialistic division of property that our three little friends had will be read in the future histories. At all events, we believe that as Carnegie, Morgan, Hill and Rockefeller have found in the "trust" the most efficient way of producing wealth, their successors must find the way to efficiently and justly distribute it. The genius of America has always been ready for the problem of the day, and signs are not wanted that a reaction against the ignorant sin of graft is started. But of all men, engineers and technical men, who know that "you cannot lie to science or bluff a chemical equation," should be in the lead in the fight for honesty. The moral idiot who defined "an honest man as one smart enough to keep out of jail," has made many young men cynics by that remark. Honesty is the best policy. Yes, it is far more than that, it is right and true as nature is right and true to her children that love her. Benedict Arnold was a noble man in comparison to him who is an example of material success by underhanded methods and has silently prostituted his powers to mammon. As our journal tries on these pages to postulate the fundamental laws of physical chemistry and commercial science, to the best of our ability, so we are glad to record our views on the present evil of our beloved country. For honesty is the only basis of human happiness.

William B. Rankine.

In our November issue we were sorry to report the death of Mr. William B. Rankine, to whom Niagara Falls owes so much. While in that issue we already gave a short sketch of his life and work, we are now enabled, through the courtesy of a personal friend of the deceased, to publish his portrait with the following appropriate notes on Mr. Rankine as a man:

It was Mr. Rankine's foresight which conceived the immense industrial importance of "Niagara harnessed," and it was his and Mr. Edward D. Adams' energy and foresightedness that provided the capital necessary for this great enterprise. Before it had been shown that electrical horse-power on a large scale could find a ready market, millions of dollars had been sunk in the gigantic wheel-pit and tunnel of this great company. Not only was capital timid in advancing money for such a project, but even the engineering talent at that time was somewhat afraid that power could be commercially developed on so large a scale.

With the completion of the power plant at Niagara the engineering end of the plan proved successful in every point and vindicated the confidence of capital. There remained the question of a market. It had been expected by many that cheap horse-power involved in the plan would attract great textile mills and other factories of a similar character to Niagara. But the true market for big blocks of power came in the establishment of entirely new industries. It was the Pittsburg Reduction Co., making aluminium, the Carborundum Co. and the Union Carbide Co. who became the great consumers of this power, thus creating an almost entirely new field of industry.

WILLIAM B. RANKINE.

Mr. Rankine's connection with the electrochemical world has always been intimate. Under his supervision the power lands at Niagara became covered with electrochemical factories. An opportunity was offered manufacturers and inventors to work out, on a commercial scale, plans which had hitherto been confined to laboratories. Mr. Rankine's stand, as encouraging the development of this class of industry, will always be held in remembrance by electrochemists.

Mr. Rankine was a man of immense activities. Since the successful utilization of Niagara's flow, Mr. Rankine has been actively engaged in building up the plant he fathered and in duplicating it on the Canadian side. He lived to see the Canadian plant finished and in operation.

Mr. Rankine had time left from his many businesses to cultivate the artistic side of his nature. He was well read in general literature, fond of practical charity, and devoted much of his time to church work, he being the chancellor of the Diocese of Western New York at the time of his death. His friends were innumerable, and he probably met more distinguished foreigners in the course of a year than any man in American private life. No distinguished party of visitors came to the United States that did not come to Niagara Falls, and coming to this city they invariably inspected the power house of the Niagara Falls Power Co. They met as host Mr. Rankine, and America could hardly have had a more polished and cultured representative.

His activity is evidenced by the number of important positions he held. He was the second vice-president and treasurer of the Niagara Falls Power Co., Niagara Junction Railway Co., and Niagara Development Co., vice-president of the Canadian Niagara Power Co., vice-president of the Francis Hook & Eye & Fastener Co., of Niagara Falls; secretary and treasurer of the Cataract Power & Conduit Co., director and chairman of the executive committee of the Natural Food Co., of Niagara Falls; of the Cataract Power & Conduit Co., of Buffalo; of the Tonawanda Power Co., and of the Suburban Power Co., secretary of the Tesla Co., a director of the Bell Telephone Co., of Buffalo; a director of the Ramapo Iron Works, Niagara Tachometer & Instrument Co., and Niagara Research Laboratories, and a trustee of the Equitable Trust Co., of New York. Mr. Rankine was a trustee of De Veaux College and a life trustee of Union College, a member of the Buffalo Club, of Buffalo, and of the University, Metropolitan, Lawyers and Alpha Delta Phi Clubs, of New York City; of the Bar Association of the City of New York, and of the New York State Bar Association.

Electric Smelting of Magnetic Iron Ore.

As was already mentioned on page 445 of our November issue, 1905, a series of tests have recently been made by Dr. David T. Day, of the United States Geological Survey, on the utilization of black sands and magnetic iron ores obtained from various points of the Pacific Coast. Dr. Day makes the statement that conditions for the electric production of steel are fully as good in Oregon as they are in Germany. From Dr. Day's preliminary report the following notes are taken:

The electrical experiments were made by Mr. C. E. Wilson. He brought from the East twenty-five carbon electrodes—each 48 inches long and 4 inches square—such as are ordinarily used in electric furnaces. The rest of his equipment was obtained in Portland from materials kept in stock or easily made at a foundry.

The first experiments were made with a "small furnace." In building this furnace a course of ordinary Carnegie fire-bricks was laid upon the ground. Upon this single course was laid a cast-iron plate, five-eighths of an inch thick, 3 feet long and 3 feet wide. On this was placed an oval sheet-iron drum, of No. 16 iron, 3 feet long by 3 feet high. The sides of this drum were lined with fire-bricks, to form a crucible 18 by 18 inches and 24 inches high. The bottom of the crucible was covered from the cast-iron plate up to the tapping hole, with broken carbon electrode. The carbon electrode to carry the current was suspended by a pulley above this furnace and connected with a balanced axle and wheel, by which it could be readily raised or lowered. The top of the furnace was covered with two double plates of riveted wrought iron, between which cold water was run. In the center of this water-jacketed cover an opening was left sufficient to allow the free play up and down of the carbon electrode.

From a transformer sub-station of the Portland Electric Co., alternating current of 1,000 to 2,000 amps., at 50 to 20 volts, were available at the terminals of the furnace.

The first run was made on Oct. 17. The charge was made up of a mixture of magnetite, coke and lime. This consisted of 200 pounds of magnetite, obtained from the sand at Hammond Station, near Astoria, Ore., at the mouth of Columbia River (analysis Fe_3O_4 79.06, TiO_2 16.00, MnO_2 2.45, silica, moisture and undetermined matter 2.49); 44 pounds of "Fairfax" coke, containing about 25 per cent of ash, and 24 pounds of lime. About 150 pounds of this charge was slowly introduced into the furnace, and within an hour there was tapped from the furnace 70 pounds of steel and slag which contained 8 per cent of iron.

On the following day the furnace was again heated, and filled with a mixture similar to that used on the first run, except that it contained less lime. Steel was successfully cast twice, making, for that day's run of 2 hours, a product of 90 pounds of steel from 300 pounds of iron ore.

The heat was sufficient to keep the entire slag in a fluid state, whether much or little titanic acid was present. No titanium went into the iron.

The slags first obtained consisted of fused iron silicates, fused oxide of iron and silicate of titanium. Later in the experiments these slags grew lighter in color and in specific gravity. It became possible also to lessen the quantity of slag produced, which was unduly large, owing to the great quantity of ash in the coal. The coke used showed an analysis 41 per cent of ash. It is difficult to procure, in that locality, coke that is well adapted to metallurgical needs.

Experiments with the small furnace having been successful, it was thought desirable to build a larger furnace, with thicker walls, in which higher temperatures might be obtained and maintained. An iron plate, 2 inches thick, 5 feet wide and 6 feet long, was therefore procured and laid upon two courses of fire-brick, to form the base of a furnace, on which was set a wrought-iron cylindrical shell one-quarter of an inch thick, 5 feet in diameter and 4 feet high. This was lined with fire-brick, the bottom having the usual lining of one course of carbon electrode bricks 4 inches in diameter. Two carbons clamped together with a water-jacketed head or clamp formed the electrode for introducing the current. The voltage was run up as high as possible—that is, from 75 to 90 volts, the limit of the current obtainable over the wires. In all respects, except these mentioned, this second furnace is identical with the first.

Iron ore from Aptos, Bay of Monterey, Cal., was smelted in this furnace on Nov. 10. This iron ore is very fine grained and contains a notable percentage of manganese. It is not so rich in titanium as the other sands that had been used. From the start this furnace made a satisfactory run, maintaining easily a high temperature and turning out a very smooth product. After a few trials the slag became as light in color as that from any well regulated blast furnace. The later products of steel were much denser than those first made, which would seem to indicate that, at the higher temperature, the process of reduction is complete, even in the short time that elapses between the beginning of reduction and the tapping. In every case, however, small blow-holes were observable in the steel. These were due to gases which formed wherever grains of magnetite were still entangled in the steel in process of reduction. The capacity of this furnace with a current of 125 volts, 1,200 amps., would be 2,000 pounds in 24 hours.

From the daily records of both furnaces it appears that the energy consumption per unit of weight of steel produced varied greatly with the amount of the charge and other factors; 1-hp. day produced from 2 to 24 pounds of steel.

News and Notes.

American Electrochemical Society.—At the meeting of the board of directors of the American Electrochemical Society, held on Dec. 2, in Philadelphia, the following gentlemen were elected members of the society: Louis Ruhl, New York; Arthur Haug, Peekskill, N. Y.; H. A. Prosser, Elizabeth, N. J.; A. W. Lewin, New Orleans, La.; Francis R. Pyne, South Bethlehem, Pa.; Harry R. Lee, South Bethlehem, Pa.; John S. Bridges, Jr., Boston, Mass. The names of the following genlemen will come up for election at the January meeting of the board of directors: M. Fukuda, Japan; Joseph H. Goodwin, Penn Yan, N. Y.; Chas. S. Palmer, Upper Montclair, N. J.; Albert Petersson, Alby, Sweden; Washington Devereux, Philadelphia, Pa.

Franklin Institute.—In a section meeting of the Franklin Institute of Philadelphia, on Dec. 2, Mr. S. S. Sadtler presented a paper on new laboratory methods and appliances, and Dr. Henry Leffmann a paper on analytical notes. On the evening of Dec. 21, Dr. J. W. Richards, of Lehigh University, lectured on electrochemical calculations.

Chemists' Club.—The Chemists' Club, of New York, elected, at its annual meeting on Dec. 13, the following officers for the coming year: William Jay Schieffelin, president; Reginald C. Woodcock and Victor G. Blode, vice-presidents; Charles Baskerville, secretary; Maxmilian Toch, treasurer; also for trustees, terms expiring 1909, Alexander C. Humphreys and Carl H. Schultz.

Palladium.—The uses of palladium are few. It is introduced at present into use as a "contact" material in the automatic gas igniters now coming into vogue. A pellet of asbestos is covered with a mixture of finely divided palladium with platinum black; as soon as illuminating gas strikes the pellet, combustion is brought about. Gas-lighting engineers are making the most of this device, since it spoils the argument of electrical engineers that the electric lamp is the only one which needs no match. Palladium has the lowest melting point of any of the platinum metals, 1,500° C.; it is more malleable than platinum, is steel-white in color, and does not tarnish. On account of its resistance to oxidation and to the action of hydrogen sulphide, it is used in the construction of the mechanical parts of fine watches, fine balance beams, scales on delicate apparatus, etc.

Niagara Falls.—The Pittsburg Reduction Co. has contracted with the Niagara Falls Hydraulic Power Co. for the delivery of 27,000 hp., and has also leased 4 acres of land extending along the river bank. The Acker Process Co. is stated to intend enlarging their plant by 30 per cent, and to negotiate with the Niagara Falls Hydraulic Power & Mfg. Co. for the increase of power.

Mining in the Butte District.—The annual output for 1905 (the month of December being estimated) by the leading mining companies of the Butte district amounted to 5,110,000 tons. From this total tonnage of ore in excess of 338,000,000 pounds of copper was produced. Of that amount the Amalgamated Company is credited with 264,000,000 pounds; United Copper, 30,000,000; Clark, 20,000,000; North Butte, 20,000,000. The Amalgamated also obtained as by-products 9,000,000 ounces of silver and 60,000 ounces of gold; United Copper, 2,000,000 ounces of silver and 6,000 ounces of gold; Clark, 1,000,000 ounces of silver and 1,600 ounces of gold; North Butte, 1,500,000 ounces of silver and 1,800 ounces of gold. The output of the Washoe smelter of the Amalgamated Company was 14,000,000 pounds of copper a month, and the Boston and Montana smelter 8,000,000 pounds a month. Ninety-two per cent of all Amalgamated ore yielded 4 per cent copper and 8 per cent of it went 8½ per cent in copper. During the last six months the Anaconda ore averaged better than 3 per cent.

A Remarkable Engineering Achievement.

BY J. RATTRAY WILSON.

A unique piece of engineering was recently accomplished at Niagara Falls, Ont. The Park & River Railroad Co., finding that the amount of water passing through their wheels was barely sufficient, resolved to raise the head by means of a dam. Seeing that the in-take of the company is situated about 600 feet from the crest of the horseshoe fall, and as the rapids at this part are very swift, it will be easily understood that the undertaking presented no ordinary difficulties.

After consideration it was resolved to build a concrete dam on shore and tip it into the river. A timber base was erected of sufficient height to allow the in-shore end of the dam,

when tipped, to be about 15 feet from the shore, and on top of this was erected a concrete pillar 50 feet high and 6 feet 1 inch square. In order that the dam might reasonably conform to the bed of the river, there were inserted every 8 feet or so wooden wedges extending half-way through the column, and to insure the pieces remaining together a heavy chain was

FIG. 1.—CEMENT TOWER STANDING.

embedded in the center, due allowances being made at the joints.

On Nov. 9, after a month's drying in the air, at 3.08 p. m., hydraulic jacks were inserted below the timber base, and shortly after, the huge mass, weighing about 300 tons, com-

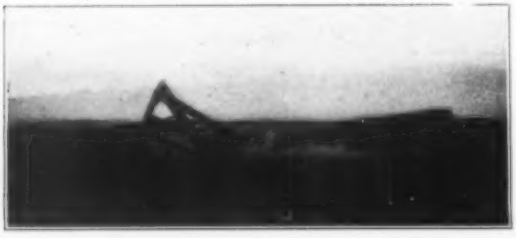

FIG. 2.—MOMENT OF STRIKING THE WATER.

menced to tip, and about 4.35 p. m. fell into its place with a grand splash.

Immediately after soundings were taken, and it was found the water in the in-take had been raised 10½ inches, as was anticipated.

Fig. 1 shows the cement tower standing before it was

FIG. 3.—PORTIONS LYING IN THE WATER.

dropped into the rapids; Fig. 2 is a snapshot of the tower just as it struck the water; Fig. 3 is a picture of the portions as they lie in the water.

Great credit is due to Mr. Isham Randolph, C. E., Chicago, who planned and carried through this novel piece of engineering to a most successful finish.

CORRESPONDENCE.

Water-Cooling of Furnace.

To the Editor of Electrochemical and Metallurgical Industry:

Sir.—I have read with considerable interest your editorial in the December issue on "Novelties in Water-Cooling Furnaces." Such ideas as you have expressed in it are in line with the general subject of refractory materials, in which subject, I notice, your journal has evinced much interest during the past year.

Without doubt it is a matter of great importance to metallurgy to have our knowledge systematized about the engineering construction of furnaces, and especially of the refractory material with which the molten or hot charge is in contact. In the zinc business, for instance, it can be almost laid down as an axiom that the fire-clay and general management of the pottery must be "like Cæsar's wife, above reproach."

In any metallurgical furnace, care expended upon the subjects of proper refractory materials and the metallic backing which holds them in place is most important. A furnace that will endure a long campaign means that the cost of repairs and renewals in the cost sheet is kept a low figure. Besides, we have a general feeling of satisfaction among all the workers of the plant at the continuous and successful operation of the furnace.

This general subject I studied with some care while metallurgist of the Lanyon Zinc Co. where I had at my disposal a research laboratory in which to test out practically my theories. In addition, while associated with Mr. Fred. W. Gordon and Mr. E. A. Uehling, while in the employ of the Lungwitz Reduction Co., I had the pleasant opportunity of hearing these two pioneer metallurgists attack the subject in the light of their own varied and prolific experience.

The ideas you express apropos of the subject of water cooling is about the result of their own experience, and I have learned from them that there is no better way of preserving the walls of the furnace than cooling the plates, against which the bricks rest, with a stream of water. In fact, the gentlemen tell me that on many occasions they repaired the bosh of an iron-furnace by simply putting in a plate and turning on the hose against this plate. Such a repair is extremely efficient and shows the general lines along which work should be carried on.

In a letter I sent to your journal in June, 1905. (Vol., III., p. 214) I stated that it was impractical, as a general principle, to water-cool an electric furnace. This I have now learned is only a "part-truth," and I now believe that where a large continuous electric furnace is in operation with an enormous output in tons of material per cubic foot of area, the number of heat units lost per ton of charge treated should not amount to over 5 or 10 per cent of the total energy required for the operation. For electrical purposes water cooling would be somewhat dangerous, but with low voltages this difficulty would not be any great factor. Where it is, it would be quite possible to cool with crude oil and carry by a pipe of insulated material the oil to a coil of iron pipes in which the oil could be cooled.

Another interesting development in the line of refractory materials for metallurgical furnaces would be, in my opinion, the use of Acheson graphite for the tap hole for either the slag or the metal. While this would not stand any rough mechanical treatment of the drill or tap-bar, yet under certain conditions this material is practically indestructible, and I have used it with success for running slags.

I note that Mr. Hiram W. Hixon has used what he calls electrode carbon in his work at the smelter of the Mond Nickel Co., of the Victoria mines, of Ontario.

New York. Woolsey McA. Johnson.

The Injurious Effect of Acid Pickles on Steel.

BY PROF. CHARLES F. BURGESS.

A most interesting phenomenon attendant upon the pickling of iron and steel articles by the use of acid solutions is the influence which such treatment exerts upon the physical properties of the metal. The attention of the metal worker is called to this repeatedly by the ruin of steel springs and other tempered articles, which, accidentally or by design, have been subjected to the action of acid solutions.

While for many years it has been known that when an acid attacks an iron article it weakens it by dissolving some of the iron, it is not so generally recognized that there is a much more serious and a far deeper seated effect, resulting in an alteration of the physical properties of the iron below the surface. The influence of the acid penetrates to some depth, so that the temper of steel may be destroyed by a few moments' immersion, and the tensile strength of untempered iron is usually diminished. This phenomenon is commonly designated by the practical worker as "rotting." It was first brought to the attention of the writer in the course of removing scale from a short length of steel wire by immersing it in a dilute sulphuric acid solution. Before immersion, this wire could be bent in a circle of less than 1 inch diameter. The jar containing the acid solution was of such dimensions that the wire had to be bent in an arc of about 8 inches diameter, the ends being near to the bottom of the vessel. While noting the action of the acid for a few seconds, the wire suddenly snapped in two, throwing some of the solution into the eyes of the watcher, thereby reducing him, for the rest of that day at least, to a mood more conducive to contemplation than to observation.

Newman (Metallic Structures, Corrosion and Prevention) speaks of this phenomenon, and refers to the investigations made by Ledebur as being an excellent experimental study of the subject. Among other things Ledebur has shown that by pickling various kinds of iron in a 1 per cent sulphuric acid solution, the susceptibility of the iron to become brittle by pickling is least with cast iron and silicon steel and most with wrought iron and high carbon steel. Combined carbon seems to increase the action and silicon to diminish it.

The effect of sulphuric acid upon iron, by which the metal is made brittle, is a subject that has also been investigated by Prof. Hughes and others, reference to whose work will be made later.

In the process of wire drawing, where the rods are frequently annealed and pickled, it has long been recognized that the strength of the metal gradually decreases with the length of the process. This, by some, has been ascribed to the decarbonization which the air exerts upon repeated heating. It is more probable, however, that the acid treatment is alone responsible for such deterioration.

It is a fact commonly accepted that galvanized iron wire, in spite of its increased section, is never so strong as the black wire from which it is made. Some investigators have held that this is due to the alloying of the zinc with the iron, but such a view is contradicted by others, and from investigations made by the writer it would appear that such alloying is extremely slight and quite insufficient wholly to account for the marked weakness produced. The heat treatment may exert some influence in the weakening process, but it seems more likely that if the pickling which is done prior to the immersion in the molten zinc bath could be dispensed with, galvanized wire would be quite as strong as black wire, barring, of course, any alteration of the temper incident to the heat treatment.

In the Transactions of the American Society of Mechanical Engineers (Vol. IX., 1888, p. 715) may be found an interesting discussion of the question, "To what extent does electroplating reduce the temper of highly hardened steel?" In this discussion it was held by some of the speakers that the idea that steel could be injured in the electroplating process was a fallacy, and it was maintained that to destroy a temper imparted to steel by heat treatment a second heat treatment is necessary, and that, therefore, nickel plating, which involves no such treatment, cannot be harmful in its effects. Others claimed that certain solutions by the use of which hydrogen is liberated upon the metal would destroy its temper, and it was stated that the acid treatment, which was frequently applied to steel in the course of preparing it for the reception of a nickel deposit, was largely responsible for the deterioration which took place.

Steel springs, such as are used in locks, clockwork mechanisms and the like, steel tape, piano wire, and many other tempered steel articles having but a small section dimension, cannot be subjected to the ordinary plating processes on account of the deterioration which takes place in the metal. Difficulties such as these were called repeatedly to the attention of the writer, eventually leading to an experimental investigation into the underlying causes and the extent of the deterioration produced by different methods of treatment, the hope being, to determine if possible, some satisfactory way of obviating the difficulty.

The concensus of opinion among those who have investigated the matter is, that the alteration of the physical properties of iron and steel by the action of acids is due to the hydrogen which is liberated. The only dissension from this view is that which holds that the acid itself penetrates into the metal through capillary or other force, the destructive action being thus continued after the metal has left the pickling solution.

That hydrogen has a capacity for exerting a marked influence on the properties of iron is demonstrated in the electrodeposition of that metal. The iron thus produced has associated with it, either in chemical or physical combination, a relatively large quantity of hydrogen. The gas may be expelled by bringing the metal to a red heat, but this expulsion involves a change in the property of the iron, which from being hard and brittle becomes soft and ductile. An apparent anomaly is the fact that steel possessing certain physical properties may be exposed to hydrogen gas under varying conditions of temperature and pressure without undergoing any material physical changes and without absorbing any appreciable quantity of the gas. If, however, the metal is exposed to hydrogen under that peculiar condition of activity, commonly known as the nascent state, the absorption of hydrogen becomes most marked. The action of acid upon iron liberates hydrogen in this peculiar condition of activity, and the iron therefore absorbs the gas.

This absorption of occlusion of hydrogen by iron has been made the subject of much research. The gaseous element is usually present, though in almost immeasurable quantities in all forms of iron. Like all other fluids, molten iron is capable of absorbing gases, and the solidified metal retains some of the gases thus taken in. Ledebur determined the amount of hydrogen which would be retained by solidified iron, and found that Martin iron (poured) containing .1 per cent of carbon and .14 per cent silicon retains .0017 per cent by weight of hydrogen. Graham (Collected Works, p. 279) found hydrogen able to diffuse through a red-hot iron pipe, and on cooling this down in an atmosphere of hydrogen the metal occluded .46 per cent of its own volume thereof. Cailletet (C. R., LXXX., p. 319) by depositing metal from its ferric chloride solution obtained metal hard enough to scratch glass and containing .028 per cent of hydrogen. Johnson (Proceedings of the Royal Society, 1875, Vol. XXII.), Hughes (*Jour. Soc. Tel. Eng.*, 1880, p. 163), Baedeker (*Zeit. d. Ver. deutsch. Ing.*, 1888, p. 186), and Ledebur (Stahl und Eisen, 1887, p. 681, and 1889, p. 745) found that iron corroded by dilute sulphuric and hydrochloric acid absorbs hydrogen. Jüptner (*Siderology*, p. 285) observes that where hydrogen is liberated in this manner the gas can diffuse through sheet iron and produce large bubbles in defective places, such bubbles being contained under con-

siderable pressure. Sir Roberts Austen (Fifth Report of Alloys Research Committee, Inst. of Mech. Eng., 1889) described the marked influence of hydrogen in electrolytic iron.

To test the correctness of the theory that the deterioration of steel in a pickling bath is due to the hydrogen which is liberated and also to find, if possible, a practical method for preventing such deterioration, was the incentive which led to an experimental investigation of the subject in the electrochemical laboratories of the University of Wisconsin. Granting that the hydrogen liberated upon the iron is alone responsible for the rotting produced in the pickling process, the remedy would, naturally, be sought in some method which would suppress the hydrogen and at the same time would not interfere with the effectiveness of the pickle in removing the scale. Various methods for attaining such a result suggested themselves, among them being the following:

The use of nitric acid of such strength as to liberate no hydrogen.

The use of acid solutions containing an additional material capable of being readily reduced by the liberated hydrogen.

The use of arsenic in the solution.

The employment of a bath containing no hydrogen.

The employment of the electric current.

Nitric acid presents objections as a pickling material for the removal of scale on account of the slight solubility which it has for black iron oxide, the tendency which iron has to become passive in solutions of certain concentrations and the absence of liberated hydrogen which would serve physically to remove the loosened scale. The reason that no hydrogen bubbles are liberated during the action of nitric acid upon iron is that the hydrogen which is replaced by the iron reacts upon the NO_3 radical, reducing it to a lower oxide. In other words, the acid itself acts as a depolarizing agent as it does when employed in a primary battery.

Materials other than the acid itself may act as the depolarizer, such being illustrated by copper sulphate, sodium nitrate and the like.

Arsenic in an acid solution exerts a remarkable influence upon the rate at which sulphuric or hydrochloric acid will attack iron. This was pointed out over half a century ago by E. Millon (*Comptes Rendus*, 1845, Vol. XXI., p. 37), who showed that the presence of certain salts and other impurities in an acid solution exert a marked effect. While iron turnings are readily acted upon by dilute sulphuric acid solution, a few drops of platinic chloride greatly increases such activity. On the other hand, arsenious acid arrests all action, and it is claimed that the iron may be left for several months in a solution containing a few drops of anaqueous solution of As_2O_3 without any appreciable action taking place. The effect of arsenic upon hydrochloric solutions is said to be similar. A. Meurice (*Bulle. de L'Assoc. Belge. Chemistes*, Vol. IX., p. 343) states that a good and a bad acid is determined by the percentage of arsenic which it contains, claiming that an acid containing .5 per cent of arsenic will clean iron wire well without effervescing and give a wire of even gauge which will not break in drawing, while with a .1 per cent solution the effect is quite the reverse. From results obtained by him it appears that the use of arsenic is advantageous in acid pickles, reducing the consumption of acid by one-half. This is contrary to the estimation in which arsenic usually is held by the pickler, who generally considers its use decidedly disadvantageous on account of the discoloration and other defects which it produces upon the pickled work.

An example of a bath containing no hydrogen, and consequently furnishing conditions impossible for the liberation of the gas, is one made of fused borax, such as is frequently used as a flux in the brazing process. It is possible that certain organic compounds might likewise meet this requirement.

The electric current, while facilitating the liberation of hydrogen at the cathode, has the opposite action at the anode, and by suitable regulation of its density the formation of hydrogen may be entirely prevented. By making the object exposed to the action of the pickling solution the anode, this suppression can be obtained.

Methods of Investigation.

In attempting to remove the thin black scale from some small tempered steel springs of a U-shape, it was found that all the ordinary acid pickles during a few moments' action produced such a rotting effect as to make the spring useless. This deteriorating effect was readily noted when an attempt was made to straighten the spring. Before having been subjected to the treatment, it could be pulled out straight without rupture, but after the acid had acted upon it rupture occurred during the straightening process.

After noting that different strengths of the ordinary acids always produced this effect various other pickles were tried, one of which was a solution of stannous chloride, such as is recommended by Brannt (*The Metal Workers' Handy-Book*, p. 246). Here it is claimed that iron may be cleaned of its oxide by immersion in a nearly saturated solution of chloride of tin, the duration depending upon the thickness of the film, 12 to 24 hours being sufficient. The solution should not contain too great an excess of acid, since in such case the iron itself will be attacked. It is recommended that the article, after its removal from the bath, should be washed in water and then in ammonia, this being followed by rapid drying.

Upon trial, a freshly prepared tin chloride solution was found to be effective in removing the thin scale from the steel spring, 1 to 2 hours being required for the operation. Whether this solution exerts a solvent action upon the scale or upon the iron itself, with a resultant loosening of the scale, was not determined, but it was found that the solution produced little brittleness. It was noted, however, that after the solution had been in use for some time, the rapidity of its action diminished, though this could be easily regenerated by the addition of a very small percentage of free hydrochloric acid.

To determine quantitatively the deteriorating influence of various solutions under consideration, it became necessary to devise other means for making observations. Two such suggested themselves. One of these has been referred to previously. It consists in bending a steel wire or a flat strip in the manner shown in Fig. 1. The support holding the bent wire is immersed in the solution, the action of which is under test. After a certain length of time, depending upon the chemical composition and strength of the solution, the wire becomes so brittle as to break. By observing the length of time necessary to produce this effect in different solutions the relative deteriorating effects of each can be approximately stated as being inversely proportional to the periods thus measured. While this method gave good results, its practice was not found satisfactory, on account of the length of time required to take each measurement and the necessity of careful watching in order to note the exact moment of rupture. The testing of one solution required a number of measurements, since different pieces of iron cut from the same strip give somewhat varying results, necessitating the taking of a number of such determinations from which an average may be secured.

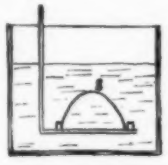

FIG. 1.—METHOD OF TESTING.

A more satisfactory method of making such tests consisted in determining the amount of flexure which a strip of steel will stand before and after being subjected to various corroding influences. Fig. 2 shows a testing device which was designed and constructed for this purpose. The piece of wire or steel strip is held in the manner shown, and by steadily turning the screw-head until rupture occurs and noting the number of turns which may be taken, a determination of the amount of bending which the strip will stand is thus secured. In

making the tests, the screw is turned as uniformly as possible, since if it is turned by jerks or is left stationary at any position for an interval of time, considerable variation in the results are obtained. The distance between the two outside knife edges of the apparatus is ½ inch, and consequently small samples may be tested, or, on a piece of wire 6 inches long several measurements may be made and the average of these secured. The screw has a pitch of 50 per inch. Five complete turns of the screw, therefore, cause a deflection of one-tenth of an inch between the middle and the two ends of a ½-inch length. In using this piece of apparatus the decrease in flexibility was taken as being a measure of the deteriorating effect of hydrogen, and it was assumed that this decrease in flexibility was approximately proportional to the difference between the number of turns of the screw required to break the sample before and after its subjection to the action of the solution under test. These assumptions are not entirely justified, since the flexibility is not strictly proportional to the distance through which the central knife edge moves. This error is so small, however, as to be masked by other experimental errors.

A steel ribbon was used in preference to wire, as reducing such errors to a minimum. This ribbon was used in the investigations, the results of which follow: It was obtained

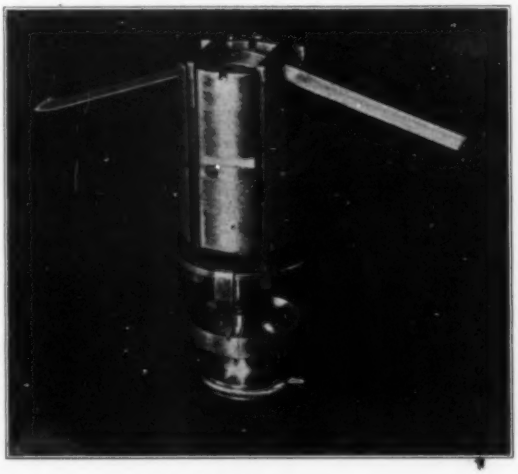

FIG. 2.—TESTING DEVICE.

directly from the factory, being a high-grade spring steel, untempered, 5-16 inch wide and .016 inch thick. It carried a thin black scale. Pieces from 8 to 12 inches long were used in making the tests, and these were immersed half their length in the solution the action of which was to be observed.

While this steel strip has the appearance of being uniform, and by means of a micrometer was found to have uniform dimensions, when subjected to the bending test some variations between samples cut from the same strip were discovered.

To state quantitatively in definite units the amount of deterioration which is produced in a given time under conditions is, of course, impossible, and the term "percentage deterioration" will be employed to designate measurements which show roughly the amount of deterioration by means of which comparison between the different samples may be made. The percentage deterioration was derived in the following manner: The samples upon which measurements were made were all cut from the same coil of steel ribbon, pieces 8 to 12 inches in length being used, and these were immersed vertically to a distance of about 6 inches in the solution under test. Three or more breaking tests were made upon the exposed and upon the unexposed portions of each sample and the average of such reading calculated. The difference between the values thus given for the two ends show approximately the amount of brittleness. The percentage which this difference bears to the number of turns required to break the uncorroded part of the specimen is the "percentage deterioration." The reduction in cross-section produced by the dissolving action of the acid on the steel while removing the scale would naturally serve to increase the apparent flexibility, so that if it were not for the deteriorating action the corroded strip would be more flexible than the uncorroded piece. Consequently, this reduction in thickness tends partially to mask the deteriorating effect in question, but in the following measurements it has been neglected as being too small to be considered, except in cases where nitric acid was employed.

RELATIVE EFFECT OF VARIOUS ACIDS.

For the purpose of determining which of the three common acids, sulphuric, hydrochloric and nitric, produce the least amount of brittleness, the following measurements were made. Normal solutions of these three acids were used. Samples of the test ribbon were immersed for various lengths of time and the percentage deterioration in each case measured. It was found that the nitric acid had the least satisfactory effect in removing the scale, though it dissolved the iron at a much greater rate than did the other two acids:

Acid Solution	Time of Immersion. Minutes.	Per Cent. Deterioration.	Weight Before Corrosion.	Loss.
n.H_2SO_4	10	3		
n.HCl	10	59	Grams.	Grams.
n.H_2SO_4	15	61	6.8162	.0313
n.HCl	15	67	6.8160	.0314
n.HNO_3	15	13	6.8080	.2540
n.H_2SO_4	20	55		
n.HCl	20	69		
n.H_2SO_4	30	57		
n.HCl	30	68.5		

From this data it may be concluded that sulphuric acid produces less deterioration than does hydrochloric, though the difference between the two is not great. The brittleness is shown to be produced mainly during the first few minutes of immersion, the values upon longer immersion remaining somewhere near constant. Some gas was liberated in the nitric acid solution, though not so much as in the others. The 13 per cent deterioration given for this acid is probably too low, since the metal which was dissolved made the strip thinner, and therefore capable of a greater amount of bending without rupture. In fact, if the strip had been left longer in the nitric solution, the bending of the corroded sample would have become greater than that of the uncorroded piece, as is brought out in the data which follows:

PERCENTAGE DETERIORATION.

Min. immersion.	1.	3.	5.	10.	15.	20.	30.	60.
	%	%	%	%	%	%	%	%
n.H_2SO_4	1.0	3.8	15.2	25.0	21.6	11.5	38.0	58.0
n.HCl	9.8	9.4	32.0	49.0	53.0	47.9	63.0	65.6
n.HNO_3	11.0	12.7	5.3	18.0	23.0	5.5	−3.0	−2.0

It is seen again from the table given above that sulphuric acid produces less brittleness than does hydrochloric; that the lower amount of brittleness in the nitric acid bath is not due to lack of hydrogen evolution alone, but more largely to the fact that the rate of the dissolution of the metal is much greater, the decrease in thickness producing greater flexibility, as shown by the 30 and 60-minute specimens which had become badly corroded. The corrosion of the samples in the other acids was almost imperceptible.

One of the peculiarities shown by this table is that there appears to be a maximum effect between 10 and 15 minutes' immersion for all the samples, after which there is first, a decrease and, subsequently, an increase. Whether this is an accidental effect or whether it is due to a definite phenomenon requires further experimental data to determine.

Influence of Arsenic.

It has been pointed out previously that the presence of arsenic causes sulphuric acid to act much less rapidly than does the pure solution, and it was sought to determine whether this would decrease the amount of brittleness as well as the rate of attack by the acid. A five normal solution (containing about 245 grams of acid per liter of solution) was employed. To a portion of this solution was added a very small quantity of arsenic in the form of arsenious acid. The resultant data follows:

Percentage Deterioration.

Minutes of immersion....	3.	10.	15.	60.
5n.H_2SO_4	52.0%	54.8%	61.0%	64.0%
5n.H_2SO_4 + As_2O_3.....	.8	8.0	2.0	9.2

These figures show most strikingly the advantage which the presence of arsenic in such pickling solutions affords. The scale was removed completely by either of the solutions and apparently with equal facility. It is frequently urged by practical picklers that arsenic is a material to be rigorously avoided in making up pickling solutions, owing to the undesirable surface which, they claim, it leaves after the removal of the scale. Such objection to its use was not borne out by the experiments cited. Indeed, the solution containing arsenic produced a surface even somewhat smoother than that left by the other pickle.

It was noticed that in the solution containing arsenic there was almost no evolution of gas, in which respect it differed from the arsenic-free solution. Measurements were then made to determine the relative rate of attack of the two solutions in question. The surfaces to be exposed to the acid were cleaned with emery cloth. The exposed surface comprised 3.75 square inches. The resultant data follows:

Time of Immersion.	H_2SO_4Aq	$H_2SO_4Aq + As_2O_3$
20 minutes.....	.0472 gram loss	.0052 gram loss
60 minutes.....	.2060 gram loss	.0022 gram loss
Total	.2532 gram loss	.0074 gram loss

These figures show the marked retardation of corrosion where arsenic was employed. On diluting the above solutions by one-half and removing scale from the samples by immersing, the losses in weight, including the weight of the scale which was removed, were .0252 grams and .0187 grams respectively, the greater loss being that noted where the pure solution was employed. The smoothness of the surface which was treated by the solution containing arsenic was much more pronounced and the brittleness of the sample much less than in the other case.

Just what is the reason for the protective effect produced by the arsenic I shall not attempt to say. Certain it is that the action of a small percentage of it in pickling solutions is remarkable. It is possible that certain other impurities might be introduced to even greater advantage, and this is a matter worthy of further investigation. The presence of antimony in a sulphuric acid solution seems to have somewhat the same effect as that exerted by arsenic, though in a lesser degree, while nitrate of bismuth has an effect only slightly less than that given by the arsenic, so far as the few measurements taken in this connection demonstrate.

Millon claims that the effect of arsenic is noticeable equally in nitric and in sulphuric solutions. Trials were made to determine whether the arsenic produced as pronounced an effect in a five normal hydrochloric acid solution as it did in a sulphuric acid solution of the same strength.

Percentage Deterioration.

Time of Immersions.	5n.HCl	5n.HCl + As_2O_3
5 minutes.....	60.4%	40.0%
10 minutes.....	71.7	53.9

Investigation showed that the tin chloride solution, the efficacy of which as a means for removing scale from tempered steel, has been pointed out previously, produced a deterioration of about 3 per cent upon the standard steel strip after an immersion of two hours' duration. To determine whether the tin itself exerts a beneficial action, a stannous chloride solution was added to the five normal sulphuric acid pickle. It was found that the deterioration was reduced in a 5 minutes' exposure by from 55 per cent to 18 per cent, and that the tin, therefore, acts somewhat in the same manner as does arsenic.

It occurred to the writer that an aluminium chloride solution might be effective also, and it was found, after making such an experiment, that spring steel could be cleaned in about 4 hours without appreciable injury to its properties. On continued immersion for several days, however, the steel became rotten. The action of the stannous chloride and the aluminium chloride solutions appeared to be somewhat similar, the advantage being in favor of the first named. It was found, however, that while the scale is completely removed the surface is not left bright, so that a subsequent scouring or other treatment becomes necessary in order to make it ready for an electro-deposit.

Brittleness Produced by Nickel Plating.

It has been suggested that the process of nickel plating is responsible for the deterioration produced in various kinds of steel and iron articles, and that such deterioration is to be traced almost directly to the effects of the pickling that is necessary. It was decided to make further tests to determine, if possible, whether the ordinary nickel plating bath plays its part in such deterioration. These tests were made by preparing three samples of spring steel for receiving a nickel coating, the following methods being employed: Sample No. 1 was freed of scale by rubbing it with emery cloth. No. 2 was pickled in the ordinary sulphuric acid solution. No. 3 was immersed in a pickle of similar nature, to which had been added a small amount of arsenious acid. The samples were then plated in the nickel ammonium sulphate solution, and were afterwards tested after the manner described above. The results obtained follow:

Percentage Deterioration in the Nickel Plating Process.

Cleaning With Emery.	H_2SO_4Aq	H_2SO_4 — Aq —As_2O_3
13.2%	18.6%	4.8%
6.9	10.5	4.8
9.3	18.6	7.2
11.9	16.2	12.0
14.3	14.0	4.8
15.5	....	7.2
Ave.. 11.85	15.58	6.8

Sample No. 2 showed the greatest amount of deterioration, and while the deterioration of No. 1 was less, yet it showed an appreciable weakening, demonstrating that the nickel plating solution in itself exerted a harmful effect on the thin steel strip. This was due, possibly, to the presence of a small amount of free acid in the solution. Whether a neutral solution would show the same effect is a question that was not put to test at the time, but it is probable that such an investigation would be of interest and, perhaps, of some practical importance. The sample which had been subjected to the pickle containing arsenic was weakened materially less than the piece which had been cleaned mechanically, and whether the arsenic not only decreased the harmful effect of the pickling solution itself but also that exerted by the plating solution, or whether the results as given may be traced to inaccuracies in the experiment, it is impossible to state without farther investigation. There seems to be little doubt, however, but that the entire nickel plating process produced harmful effects in certain

classes of work, where the section of the metal treated is so small as to make the affected part a considerable percentage of the whole.

SUPPRESSION OF HYDROGEN EVOLUTION.

The experiments above given, as well as many others which are not recorded here, seem to show almost beyond question that the brittleness or "rotting" of iron and steel is due to the penetration into its pores of hydrogen rather than of acid, so that any method which would prevent the liberation of hydrogen would do away with the usually consequent brittleness. If nitric acid of such strength that no hydrogen is evolved be used, a bent steel wire may be completely dissolved without breaking, while when other acids are employed the wire snaps in two before corrosion has proceeded to any appreciable degree. If sodium nitrate be added to a sulphuric acid solution the liberation of hydrogen can be prevented and it may thus serve a most useful purpose. An objection to its use, however, would seem to lie in the fact that the removal of the black oxide scale proceeds less rapidly in its presence.

Another experiment which was performed, but which was not original with the author, was the "annealing" of a piece of steel wire which had been made brittle through the liberation of hydrogen upon it. This brittleness had been produced by making it the anode in a sodium hydroxide solution from which the oxygen was liberated. The influence of this oxygen appeared to extend a slight distance below the surface of the iron, neutralizing the hydrogen which had been absorbed previously. In this way electrolytic annealing may be effected without the application of heat. Such a method is not of any practical value, however, on account of its incompleteness and slowness of action.

The suggestion has been made that the corrosion of acids may be advantageously replaced by electrolytic corrosion, a method which, by the way, has been made the subject of a number of patents. If a steel article from which a surface scale is to be removed be suspended as the anode in a dilute sulphuric acid or a sodium sulphate solution, corrosion may take place without the liberation of hydrogen. While this might be of advantage in preventing the weakening of the metal through the influence exerted by the hydrogen, it has its patent disadvantages, since it interferes with the chief purpose of the pickling process, *i. e.*, the removal of the scale. Since this removal is effected not so much by the actual solvent action of the pickle as by destroying its adherence to the underlying metal, a process which is assisted in marked degree by the liberation of the gas bubbles, it is usually disadvantageous to attempt a suppression of hydrogen liberation.

To avoid all necessity of pickling tempered steel springs, preparatory to plating, it may be possible that the tempering could be done in such a way as to prevent the formation of the oxide scale. With the idea of bringing about such a result an experiment was undertaken by covering the melted lead tempering bath with a layer of borax. Upon immersing a steel spring into the lead, through the layer of borax, the oxide was dissolved, and after subsequent immersion in oil and water a bright surface, ready for electroplating, was obtained. In some such way the disadvantages attendant upon the usual pickling process might be avoided.

The harmful effect which hydrogen exerts is an additional argument for the substitution of the sand blast for the ordinary pickling method, but its universal adoption can hardly be looked for on account of the greater expense that would be entailed, especially in the handling of small work.

Perhaps the most important feature brought out by the work here recorded is the demonstration of the marked influence which small quantities of impurities exert in acid solutions, while the fact that much additional work is necessary before a complete understanding of this will be available, is likewise shown.

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Metallurgical Calculations.

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ARTIFICIAL FURNACE GAS.

MOND GAS.

In the Mond producer, an excess of steam is introduced with the heated air used for combustion; the producer is thus run much colder than the ordinary producer, and far more carbon dioxide is present in the gas. In fact, the gas, compared with ordinary producer gas, is very high in carbon dioxide (10 to 20 per cent), very high in hydrogen (20 to 30 per cent), very low in carbon monoxide (10 to 15 per cent), low in nitrogen (40 to 50 per cent), and carries an extraordinary amount of undecomposed moisture. The fuel used is low-grade bituminous slack, and the object of using so much steam is to keep the temperature in the producer so low that a maximum amount of the nitrogen in the coal is evolved as ammonia. The gas is cooled to ordinary temperature by contact with water spray, so that all but a small amount of moisture is condensed, the ammonia is removed by dilute sulphuric acid, and the cold nearly dry gas is then used for gas engines or in furnaces.

The calorific power of the gas is not low, because the high proportion of hydrogen compensates for the low carbon monoxide, while the great heat evolved by the large formation of carbon dioxide has been mostly absorbed in decomposing steam, and is, therefore, potentially present in the gas in the form of hydrogen.

Problem 16.

Bituminous slack coal used in Mond producers for generating gas for a gas-engine power plant contained:

Moisture	8.60	per cent
Carbon	62.69	"
Hydrogen	4.57	"
Oxygen	10.89	"
Nitrogen	1.40	"
Ash	10.42	"

Calorific power, determined in a bomb calorimeter, water condensed, 6,786 Calories per unit of dried fuel. Ashes produced 268 pounds per ton (2,240 pounds) of moist slack used; contains 12 per cent of carbon.

Air used for running is heated to 300° C. by the waste heat of producer gases, and carries in 2½ tons of water as steam (at same temperature) for every ton of fuel burnt. The steam is generated by a tubular boiler run by the escape gases from the gas engines, but is heated from 100° C. to 300° C. by the waste heat of the producer gases. The latter escape from the producer at 350° C.

Composition of waste gases passing out of condensers at 15° C.:

Carbon monoxide (CO)	11.0	per cent
Hydrogen (H^2)	27.5	"
Marsh gas (CH^4)	2.0	"
Carbonic oxide (CO^2)	16.5	"
Nitrogen (N^2)	41.3	"
Water vapor (H^2O)	1.7	"
	100.0	

Assume all the nitrogen of the fuel to form ammonia gas NH^3.

Required:

(1) The calorific power of the Mond gas.
(2) The volume of gas produced per ton of fuel used.
(3) The efficiency of the producer.
(4) The weight of steam which is decomposed in the producer.
(5) The proportion of the calorific power of the fuel saved to the gas by the decomposition of steam.

(6) The proportion of the heat generated in the producer which is saved to the gas by the decomposition of steam.

(7) The proportion of the calorific power of the coal lost from the producer by radiation and conduction.

Solution: (1) One cubic foot of the gas at 0° C. would generate the following amounts of heat (water uncondensed).

$CO = 0.110$ cubic feet $\times 3062 =$	336.8	ounce Calories
$H^2 = 0.275$ cubic feet $\times 2613 =$	718.6	" "
$CH^4 = 0.020$ cubic feet $\times 8598 =$	172.0	" "
Total =	1227.4	" "
=	76.7	pound "
=	138.1	B. T. U.
Per cubic meter =	1227.4	kilo. "

If measured at 15° C. (60° F.) the above values will be reduced by the factor $273 \div (273 + 15)$, and become

Per cubic foot = **72.7** pound Calories
Per cubic meter = **1163** kilo. " (1)

(2) Carbon in 1 cubic foot of gas at 0° C.:

In CO 0.110×0.54 ounces
In CH^4 0.020×0.54 "
In CO^2 0.165×0.54 "

0.295×0.54 " = 0.1593 ounces
= 0.009956 pounds

Carbon going into gas per pound of fuel burnt:

Carbon in fuel 0.6269 pounds
Carbon in ashes $\frac{268}{2240} \times 0.12 = 0.0144$ "
Carbon in gas = 0.6125 "

Volume of gas (at 0° C.) per pound of fuel used:

$$\frac{0.6125}{0.009956} = \mathbf{61.52} \text{ cubic feet}$$

Per ton of 2240 pounds = **137.805** cubic feet

At 15° C. (60° F.)

$$= 137{,}805 \times \frac{273 + 15}{273} = \mathbf{145.375} \text{ " " (2)}$$

(3) The calorific power of the dried fuel is given as 6,786 Calories per pound, water condensed. Since one pound of wet fuel contains 100 — 8.60 = 91.40 per cent dried fuel, the calorific power of 1 pound of wet fuel, moisture condensed, is

$6{,}786 \times 0.9140 = 6{,}202$ pound Calories.

But, 1 pound of wet fuel would produce, on combustion,

$0.0860 + 9\ (0.0457) = 0.4973$ pounds moisture,

which, remaining vaporized at 15°, would retain

$0.4973 \times 596 = 296$ Calories,

leaving the net metallurgical calorific power as

$6{,}202 - 296 = 5{,}906$ Calories.

The 61.52 cubic feet of gas produced per pound of moist fuel will have a calorific power, burnt cold, of

$61.52 \times 76.7 = 4{,}719$ Calories,

making the efficiency of the producer, on fuel consumed in it,

$$\frac{4{,}719}{5{,}906} = 0.799 = \mathbf{79.9} \text{ per cent.} \quad (3)$$

The above figure is true only on the assumption that the steam used is obtained from waste heat, and therefore does not require the combustion of extra fuel.

(4) The gas produced contains, per cubic foot, the following amount of hydrogen, free and as CH^4:

As H^2 0.275 cubic feet $\times$ 0.09	= 0.02475	ounces
As CH^4 0.040 cubic feet $\times$ 0.09	= 0.00360	"
Sum =	0.02835	"
	= 0.001772	pounds
Per pound moist fuel = 0.001772×61.52	= 0.1090	"
Present as ammonia gas $0.0140 \times (3 \div 14)$	= 0.0010	"
Total (not including H as water)	= 0.1100	"
Hydrogen in 1 pound of coal	= 0.0457	"
Hydrogen from decomposition of steam	= 0.0642	"
Water decomposed in the producer	= **0.5787**	" (4)

Since the steam introduced weighs 2.5 pounds for every pound of fuel burnt, we see that only

$$\frac{0.5787}{2.5} = 0.2315 = \mathbf{23.15} \text{ per cent}$$

of the steam introduced is decomposed.

[In the writer's opinion this unused 76.85 per cent can only pass in and pass out carrying out sensible heat, and it seems a very wasteful method of keeping down the temperature in the producer. From the standpoint of regarding the 2 pounds of steam as a mere absorber of sensible heat, it could probably be replaced by some of the gases of combustion from the gas engine or open-hearth furnace. The products of combustion of the above gas would contain approximately

Nitrogen	68.7 per cent
Carbon dioxide	14.7 "
Water vapor	16.6 "

And if the ½ pound of water vapor decomposed in the producer were thus supplied, it would bring in, per pound of coal burnt,

Nitrogen	41.2 cubic feet
Carbon dioxide	8.8 "
Water vapor	9.9 "

And if the CO^2 thus introduced were reduced to CO, as it probably would be, the gases would receive from this source

Nitrogen	41.2 cubic feet
Carbon monoxide	27.5 "
Hydrogen	9.9 "

Thus producing gas quite up to standard as regards combustibles, while the heat absorbed in the reduction of CO^2 to CO would cool the fire down quite as effectually as the extra steam now used.]

(5) The steam decomposed, 0.5787 pounds per pound of fuel burnt, may be assumed to be at 100° C. on entering the fire, and to therefore absorb 3,196-pound Calories per pound of steam decomposed. The heat absorbed in the producer, and thus transferred into potential calorific power is, therefore,

$3196 \times 0.5787 = 1850$ pound Calories,

which expressed in per cent of the calorific power of the fuel is

$$\frac{1850}{5906} = 0.313 = \mathbf{31.3} \text{ per cent.} \quad (5)$$

(6) The heat generated in the producer equals the calorific power of the coal minus the heat lost by carbon in the ashes, minus the calorific power of the gases, plus the heat absorbed in decomposing steam. The loss by carbon in the ashes is

$$\frac{268}{2240} \times 0.12 \times 8100 = 117 \text{ Calories.}$$

The heat generated in the producer is, therefore,

$5906 - 117 - 4719 + 7850 = 2920$ Calories,

equal to $2920 \div 5906 = 49.4$ per cent of the calorific power of the coal. Of this, 1850 Calories is absorbed in decomposing steam, which is $\frac{1850}{2920} = \mathbf{63.4}$ per cent of the total heat generated. (6)

(7) There are 2920 Calories generated in the producer, of which 1850 are absorbed in decomposing steam,, leaving 1070 Calories to supply radiation and conduction and as sensible heat in the hot gases, to which must be added the sensible heat in the hot air and steam used at 300° C.

The air used per pound of coal is found from the nitrogen in the gases:

Nitrogen in 1 cubic foot of producer gas = 0.413 cubic foot
Nitrogen in 61.52 cubic foot of producer gas = 25.40 "
Air used = 25.4 ÷ 0.792 = 32.08 "
Steam used = (2.5 × 16) ÷ 0.81 = 49.40 "

Heat in steam and air at 300° C. (from 15° C.):

$32.08 \times 0.3116 \times 285 =$ 2850 ounce Calories
$49.40 \times 0.3872 \times 285 =$ 5450 " "

Sum = 8300 " "
= 519 pound Calories

Total heat radiated, conducted and in hot gases:

1070 + 519 = 1589 Calories.

The heat in the hot gases is as follows, per cubic foot of gas produced:

CO, H^2, N^2	$0.110 \times 0.313 \times 335$, $0.275 \times 0.313 \times 335$, $0.413 \times 0.313 \times 335$	= 83.7
CO^2	$0.165 \times 0.450 \times 335$	= 24.9
CH^4	$0.020 \times 0.460 \times 335$	= 3.1
Sum		= 111.7 ounce Calories
		= 7.0 pound Calories

Per pound of coal burnt:

$7.0 \times 61.52 = 430$ pound Calories

To this must be added the heat in undecomposed water vapor in the gases, as follows:

Steam used per pound of coal = 2.50 pounds
Steam decomposed per pound of coal = 0.58 "
Steam remaining in gases = 1.92 "
Moisture in coal = 0.086 "
Total in gases = 2.006 "
Volume = (2.006 × 16) ÷ 0.81 = 39.6 cubic feet

Heat contained in this at 350° C.:

$39.6 \times 0.395 \times 335 =$ 5240 ounce Calories
= 328 pound Calories

Total heat in producer gases:

430 + 328 = 758 Calories

Heat lost by radiation and conduction:

1589 — 758 = 831 Calories

Proportion of calorific power of coal thus lost:

$$\frac{831}{5906} = 0.141 = 14.1 \text{ per cent} \qquad (7)$$

When Mond gas is heated in the regenerator of an open-hearth furnace it changes considerably in composition, as is shown by the following analyses made by Mr. J. H. Darby, on gas dried before analysis:

	Before Regenerator.	*After Regenerator.*
Carbonic acid gas, CO^2	17.8	10.5
Carbon monoxide, CO	10.5	21.6
Ethylene, C^2H^4	0.7	0.4
Methane, CH^4	2.6	2.0
Hydrogen, H^2	24.8	17.7
Nitrogen, N^2	43.6	47.8
	100.0	100.0

The above changes are very interesting, and their discussion profitable. Before heating, the gas burns with a non-luminous flame; after heating, it burns with a brilliant white flame. Let us inquire:

(1) What chemical change occurs during the heating?
(2) What are the relative volumes of the gas before and after heating (excluding water)?
(3) What change in the calorific power is produced by the heating?

(1) An inspection of the analyses shows undoubtedly that at a high temperature the CO^2 cannot hold all its oxygen in the presence of such a large amount of hydrogen, and that the following reaction must occur:

$$\underset{\text{I}}{CO^2} + \underset{\text{I}}{H^2} = \underset{\text{I}}{CO} + \underset{\text{I}}{H^2O}$$

The figures given do not check exactly, but assuming that the above reaction takes place, we can find to what extent, by expressing the composition of the gas after heating for the same amount of *nitrogen* as was in the gas before heating, since this gas is unchanged:

	Before Heating.	*After Heating.*	*Loss or Gain.*
CO^2	17.8	9.6	—8.2
CO	10.5	19.7	+9.2
H^2	24.8	16.1	—8.7
N^2	43.6	43.6	0.0

Since, according to the reaction written, the volume of CO^2 reduced to CO will be equal to the volume of H^2 thus consumed, and will produce an equal volume of CO; the above table proves, within the probable limits of error, that the reaction written actually takes place.

The separation of luminous carbon is probably due to the splitting up of C^2H^4.

The relative volumes of the heated and unheated gases will be inversely as the percentage of nitrogen in each (since this gas is unchanged), viz.: as 47.8 to 43.6, or as 100 to 91.2. The contraction, 8.8 parts, would again correspond almost exactly to the amount of water formed in the assumed reaction, which would be equal to the hydrogen so used, thus giving another check on the validity of the reaction assumed to take place.

The calorific power of 1 cubic foot of original gas is:

CO	$0.105 \times$	3,062 =	321.5 ounce Calories
C^2H^4	$0.007 \times$	14,480 =	101.4 " "
CH^4	$0.026 \times$	8,598 =	223.5 " "
H^2	$0.248 \times$	2,613 =	648.0 " "
		Sum =	1294.4 " "
		=	80.9 pound "
	Per 100 cubic feet	=	8090.0 " "

The calorific power of 1 cubic foot of heated gas is:

CO	$0.216 \times$	3,062 =	661.4 ounce Calories
C^2H^4	$0.004 \times$	14,480 =	57.9 " "
CH^4	$0.020 \times$	8,598 =	172.0 " "
H^2	$0.177 \times$	2,613 =	462.5 " "
		Sum =	1353.8 " "
		=	84.6 pound "

For 91.2 cubic feet the calorific power would be $84.6 \times 91.2 = 7715$ pound Calories.

The net conclusion is that the heated gas (aside from its sensible heat) gives less heat by combustion in the furnace per unit of coal gasified in the producers than the corresponding quantity of unheated gas; but the difference is only some 4 per cent. On the other hand, the calorific power of the heated gas per cubic foot is some 5 per cent greater than that of the unheated gas, and, therefore, its calorific intensity will have been increased by the heating—quite aside from the question of its temperature being higher, and therefore its sensible heat greater.

4. WATER GAS.

This gas is made intermittently, by first burning part of the

fuel until the fire is very hot, and then introducing steam, cool or superheated, into the fire. The reaction producing the gas is:

$$\underset{\text{I}}{C} + \underset{\text{I}}{H^2O} = \underset{\text{I}}{CO} + \underset{\text{I}}{H^2}$$

And if the reaction is complete, and only carbon is present as fuel, the gas produced is theoretically composed of equal parts by volume of CO and H^2, the volume of each of these being equal to that of the steam used (if measured at the same temperature and pressure.)

Deviations from this ideal composition are caused in practice by the occurrence of undecomposed steam in the gas, also of CO^2 and N^2, which come from the residual gas formed during the heating up of the fire, some of which will get into the first portion of the water-gas produced, and also hydrocarbons, tar and ammonia from the distillation of the fuel. A typical analysis of water-gas, given by Mr. W. E. Case, is:

Hydrogen (H^2)	48.0
Carbon monoxide (CO)	38.0
Methane (CH^4)	2.0
Carbon dioxide (CO^2)	6.0
Nitrogen (N^2)	5.5
Oxygen (O^2)	0.5

The production of water-gas is more expensive than that of other artificial producer gases, because of the large amount of steam necessarily required, the heat lost during the heating up, and the essentially intermittent character of the operation. Its essential advantages are its very high proportion of combustibles, averaging 90 per cent, and the consequent high calorific intensity which it is capable of producing. (Uncarburetted, it is well known that water-gas is a valuable domestic fuel, and illuminant when used in mantle burners; carburetted, it forms our principal illuminating gas, and as such is manufactured on an immense scale. We will treat here only of its metallurgical uses.)

Discussing the manufacture of the gas, the first step is the heating up of the fuel. This is accomplished by blowing air through it. At this point we can distinguish two systems. The older one is that of blowing in air under moderate pressure, which passes through the fire at moderate velocity, and produces a fair grade of ordinary producer gas. This gas is either wasted, or burned in furnaces requiring such quality of gas, or burned in regenerators where heat is stored up to be utilized in the next stage in superheating steam. The newer system is to blow in air at high pressure, such that a large percentage of carbon dioxide remains in the gases, thus nearly completely burning what carbon is oxidized, and storing up a corresponding quantity of heat in the remaining carbon. The incombustible gases produced are passed through a recuperator or regenerator, where their sensible heat is partly communicated to the steam used, so as to superheat it when forming water-gas. This system consumes the minimum of carbon in "heating up" the fuel, saves time in this unproductive period, and allows the producer to be run longer "on steam." In practice the fuel is probably raised to an average temperature of 1500° C. during the heating up.

We can calculate the efficiency of this heating up, that is, the proportion of the calorific power of the carbon burnt which is stored up in the remaining fuel, if we know how much fuel is in the producer, how much air is blown through, the composition of the gases produced, and the average rise in temperature of the fuel. Since this operation is, however, only supplementary to the real formation of water-gas by the decomposition of steam, we will first make calculations upon the cooling down period, during which water-gas is made.

During the use of steam the reaction absorbs heat, and the producer rapidly cools. Steam is passed through until the temperature of the fuel is 800° C., and must then be stopped, because between 800° and 600° the reaction is mostly

$$C + 2H^2O = CO^2 + 2H^2$$

resulting in a rapid increase of CO^2 in the gas. The heat to decompose steam is furnished partly by the oxidation of carbon to CO, and partly by the sensible heat in the carbon itself. Since the carbon, from temperatures of about 1000° C. up has a specific heat of 0.5, we can easily calculate how much steam can be decomposed before the temperature falls to 800°.

Problem 17.

A Dellwick-Fleischer water-gas producer contains 3 tons of coke (90 per cent carbon), heated up to 1500° C. Steam, heated to 300° C., is passed through for 8 minutes, until the temperature of the gas escaping is 700° C., or 800° at the fuel bed. The composition of the gas is (Prof. V. B. Lewes):

Hydrogen	50.0
Carbon monoxide	40.0
Carbon dioxide	5.0
Oxygen	1.0
Nitrogen	4.0

Assume 9000 Calories per minute lost by radiation and conduction.

Required: (1) The amount of steam used in the 8 minutes. (2) The volume of gas produced in the 8 minutes.

(1) The amount of steam which could have been used is limited by the available heat to decompose it. The latter is furnished by

(*a*) Oxidation of carbon to monoxide.
(*b*) Oxidation of carbon to dioxide.
(*c*) Sensible heat of the carbon and ash of fuel.
(*d*) Sensible heat of the steam used.

While the items of heat absorption and loss are:

(*e*) Decomposition of the steam.
(*f*) Sensible heat in the gases.
(*g*) Radiation and conduction.

The simplest way to arrive at a solution is to make a few necessary assumptions, and to then let X represent the weight of steam used. The assumptions are that the average temperature of the fuel bed falls to 1000° C., that the average temperature of the escaping gases is $(1500 + 700) \div 2 = 1100°$ C., that the average specific heat of carbon in the range 1000 — 1500 is 0.5, and of the ash of the fuel 0.25. Then, casting up a heat balance sheet in terms of X, we can finally arrive at an expression for the heat which was available during the 8 minutes for decomposing steam, and thus at the weight of steam decomposed, and (making this equal to X) at a solution.

(*a*) The analysis of the gas shows that eight times as much carbon was burnt to monoxide as to dioxide, making the equation of combustion:

$$9C + 10H^2O = 8CO + CO^2 + 10H^2$$

By weight, $8 \times 12 = 96$ parts of carbon was burnt to CO per $10 \times 18 = 180$ parts of steam used, or 0.533 parts per one part of steam. The heat generated in forming monoxide is, therefore:

$$0.533 \times X \times 2430 = 1296\ X \text{ Calories}$$

(*b*) Only one-eighth as much carbon burns to dioxide, giving, therefore, as the heat evolved:

$$(0.533 \div 8) \times X \times 8100 = 540\ X \text{ Calories}$$

(*c*) 3000 kilos, of fuel, representing 2700 kilos. of carbon and 300 kilos. of ash, cool from 1500° to 1000°:

$$2700 \times 0.50 \times 500 = 675{,}000 \text{ Calories}$$
$$300 \times 0.25 \times 500 = 37{,}500 \text{ "}$$
$$\text{Sum} = 712{,}500 \text{ "}$$

(*d*) $X \div 0.81$ will be the volume of the steam used at normal conditions, which brings in considered only as vapor at 300°:

$$(X \div 0.81) \times 0.385 \times 300 = 93.5\ X \text{ Calories}$$

The sum total of (a) + (b) + (c) + (d) gives the total available heat, viz.:

1929.5 X + 712,500 Calories

(*e*) The steam used requires for its decomposition, considered theoretically as cold steam, producing cold products:

$(X \div 9) \times 29{,}042 = 3227$ X Calories

(*f*) The gas being 50 per cent hydrogen, and the latter being equal to the volume of steam used, the volume of gas must be $2 \times (X \div 0.81)$, which multiplied by the mean specific heat of gas of this composition between 0° and 1100° per cubic meter, and by the temperature, will give the heat thus carried out of the producer:

$2(X \div 0.81) \times 0.347 \times 1100 = 942.5$ X Calories

(*g*) $9000 \times 8 = 72{,}000$ Calories

The sum total of (e) + (f) + (g) gives the total heat distribution, viz.:

4,169.5 X + 72,000 Calories

Since the heat available equals the heat distributed:

$$1{,}929.5\,X + 712{,}500 = 4{,}169.5\,X + 72{,}000$$

or $X = 286$ kilograms (1)

(2) The volume of this steam, at assumed standard conditions, would be

$286 \div 0.81 = 353$ cubic meters,

and of gas, since it is 50 per cent hydrogen,

$353 \times 2 = 706$ cubic meters

The above figures represent the maximum attainable production, on the assumption that sufficient steam-generating power is available to furnish the steam, and that the fuel in the producer is of small size and the bed so uniform that the production of gas is regular all over it. In practice, figures considerably below this are attained, but it is always well to know the possible maximum which is attainable.

Problem 18.

In a Dellwik-Fleischer water-gas producer the heating up is accomplished in 2 minutes by blast from a Root blower, furnishing air through a 9.5-inch pipe at a total water-gauge pressure of 19 inches of water, temperature of air 15° C. The gases escaping from the producer analyze:

Carbon dioxide	17.9 per cent
Carbon monoxide	1.8 "
Nitrogen	78.6 "
Oxygen	1.7 "

Temperature of waste gases 900° C.; heat lost by radiation and conduction 9000 Calories per minute; assume producer to contain 3000 kilos. of fuel, consisting of 90 per cent carbon and 10 per cent ash.

Required: (1) The average rise in temperature of the fuel bed.

(2) The proportion of the heat generated which is thus stored up as useful heat for producing water-gas.

(3) Assuming that the production of water-gas lasts 8 minutes, during which 2500 Calories are absorbed from the fuel bed per kilogram of steam used, what should be the steam supply in kilograms per minute?

(4) The ratio between the volume of air supplied during the blowing up period and the weight of steam used in the gas-making period.

Solution: (1) We must first find the amount of air furnished by the blower. To do this, we calculate the pressure head in terms of air at 15° C., instead of water, and then apply the well-known formula $V = \sqrt{2g.h.}$ Water is 772 times as heavy as air at 0° C., and, therefore, 19 inches of water pressure would represent $19 \times 772 \div 12 = 1222$ feet of air pressure (that is, a column of fluid as light as air, 1222 feet high). But air at 15° is lighter still than air at 0°, in the ratio 273 to 288, so that the air pressure measured in terms of air at 15° will be

$$1222 \times \frac{288}{273} = 1290 \text{ feet}$$

The velocity of the air supplied will therefore be, in feet per second:

$$V = \sqrt{64 \times 1290}$$
$$= 287 \text{ feet per second,}$$

and the volume delivered, per minute, at 15° C.:

$$287 \times 60 \times (0.7854 \times 9.5 \times 9.5 \div 144) \text{ cubic feet}$$
$$= 17{,}220 \times 0.492 = 8472 \text{ cubic feet,}$$

which, in terms of air at 0° C., would be

$$847 \times \frac{273}{288} = 8050 \text{ cubic feet}$$
$$= 228 \text{ cubic meters}$$

The volume of waste gases produced in the 2 minutes can be found from the relative percentages of nitrogen in the air (79.2), and in the gases (78.6), as follows:

$$228 \times 2 \times \frac{79.2}{78.6} = 459.5 \text{ cubic meters}$$

Containing, therefore, from its analysis:

Carbon dioxide	82.25	cubic meters
Carbon monoxide	8.27	" "
Oxygen	7.81	" "
Nitrogen	361.15	" "
	459.48	" "

The carbon burnt to CO^2 and CO will be

C to CO^2	$82.25 \times 0.54 =$	44.42 kilos.
C to CO	$8.27 \times 0.54 =$	4.47 "
	Sum =	48.89 "

And the heat thus generated:

C to CO^2	$44.42 \times 8100 =$	359,800 Calories
C to CO	$4.47 \times 2430 =$	10,860 "
	Sum =	370,660 "

To find the amount of this heat left in the producer at the end of the 2 minutes blowing up, we must subtract the $2 \times 9000 = 18{,}000$ Calories lost by radiation and conduction, and then, in addition, the heat carried out by the hot gases, at an average temperature of 900° C., which latter will be:

CO, O^2, N^2	$377.25 \times 0.327 \times 885 =$	109,150 Calories
CO^2	$82.25 \times 0.571 \times 885 =$	41,565 "
	Sum =	150,715 "

Heat left in the fuel bed:

370,660 — 168,715 = 201,945 Calories

Heat capacity of the fuel bed per 1° C.:

3000×0.9 kilos. carbon	$\times 0.5 =$	1350 Calories
3000×0.1 kilos. ash	$\times 0.25 =$	75 "
	Sum =	1425 "

Average rise in temperature of the fuel bed:

$$\frac{201{,}945}{1425} = 142° \text{ C.} \quad (1)$$

(2) The useful heat thus stored up in the fuel bed amounts to the following proportion of the total heat generated during the blowing up:

$$\frac{201{,}945}{370{,}660} = 0.545 = 54.5 \text{ per cent} \quad (2)$$

(3) Steam which can be decomposed in the gas-producing period:

$$\frac{201{,}945}{2500} = 80.8 \text{ kilograms}$$

$$= 10.1 \text{ kilograms per minute} \qquad (3)$$

(4) Air supplied in 2 minutes = 456 cubic meters. Steam used in 8 minutes = 80.8 kilograms.

$$\text{Ratio} = \frac{80.8}{456} = 0.177 \text{ kilos. steam per 1 m}^3 \text{ air} \qquad (4)$$

$$= 0.117 \text{ ounce steam per 1 ft}^3 \text{ air}$$

$$= 1.1 \text{ pounds steam per 100 ft}^3 \text{ air}$$

[The eleven instalments of this treatise on Metallurgical Calculations which have so far been published are now in press, and will appear as Part I. of the treatise in book form. (See publisher's announcement on another page.) Subsequent instalments appearing during 1906 will appear as Part II., and those of 1907 as Part III., concluding the treatise. The parts will be paged consecutively, so as to permit of combining into one volume, with index, when completed.]

Electrolytic Copper.[1]

By Lawrence Addicks.

The advent of the dynamo made electrolytic copper at once possible and necessary. The consumption of copper pursuant upon the generation and transmission of electric power in quantities never dreamed of in the days of primary batteries, has many times exceeded the output obtainable from the few sources of the native metal which will yield a product of satisfactory conductivity without electrolytic treatment.

The fact that certain mines in the region of the Great Lakes yield a mineral so free from objectionable impurities that a high-grade copper is obtainable directly by a simple furnace scorification, early gave Lake copper a premium in the market that electrolytic competition even yet has not entirely wiped out. For almost all purposes there should be no hesitation whatever to-day in specifying electrilytic copper. In conductivity it is superior to nearly all brands of Lake, and in mechanical properties it leaves little to be desired.

There are a few classes of work in which the metal is subjected to very severe punishment, such as in the making of cartridges, where Lake seems to stand up better than electrolytic, although even here it is a question how much to allow for the trade prejudices of the older generation of mill foremen who clung so tenaciously to the perplexing system of wire gauges of but a few years past. Any such advantage in Lake copper must be attributed to the fact that it is not so clean as electrolytic. A small quantity of arsenic, for example, while exceedingly detrimental to the conductivity, will appreciably improve the mechanical properties of copper. At one time arsenic was considered necessary in English specifications for fire-box copper. Each year a greater proportion of the world's output is electrolytically refined, and it seems probable that before long there will be but two grades of copper on the market—high conductivity copper, which will include electrolytic and picked brands of Lake, and casting copper, covering all material which will not pass a conductivity requirement of 98 per cent annealed.

The ideal electrolyte for refining copper would be one chemically inert as a solvent but capable of electrochemically dissolving copper, and of zero specific resistance. These conditions are most nearly met by an acidulated sulphate solution, and this has the additional commercial advantage of employing one of the cheapest of chemicals—sulphuric acid. A sufficiently high percentage of sulphuric acid may be carried to make the specific resistance very low. There is a slight redissolving of the cathode copper, but not in serious amount. Gold is untouched and silver practically so.

It is customary to carry a minute percentage of some soluble chloride as a constituent of the electrolyte which would throw down as chloride any silver which might be dissolved and also tend to slime antimony as oxychloride. Some claim that smoother cathodes result from the presence of chlorine. While the actual benefits from this ingredient are open to question, it certainly does no harm, and the refiner is often morally sustained by its presence.

In American refineries high-grade anodes are universally used. Usual compositions are:

Copper	98 to 99.5	per cent
Silver	0 to 300	ounces per ton
Gold	0 to 40	ounces per ton
Arsenic	0 to 2	per cent

Small amounts of antimony, bismuth, iron, nickel, sulphur, selenium, tellurium and silicon.

Impurities with soluble sulphates go entirely into solution and grow cumulatively. Selenium and tellurium and the precious metals go entirely into the slimes. We have, therefore, a triple separation. The usual products are only copper at the cathode, silver and gold from the slimes, and sometimes copper and nickel sulphates from the electrolyte. Selenium and tellurium, especially the latter, are easily recoverable from the slimes, were there sufficient market. Tellurium is an element almost without use in the arts. Small amounts are used in medicine, but the output of one of our copper refineries for one day would stock a large chemical supply house with tellurium enough to last a year. Arsenic, antimony and bismuth go partly into solution, partly into the slime, depending on the nature of the form of combination in which they exist in the anode and various secondary reactions taking place in the electrolyte.

Arsenic is the most difficult impurity with which to deal. If much is present in the anode, say over 1 per cent, it rapidly grows in the solution and necessitates a large expenditure for purifying to hold it down. With small quantities it seems to slime more rapidly, and no purifying at all is necessary. With other conditions properly cared for, satisfactory cathodes can be produced in an electrolyte running 2 per cent arsenic, though this is considerably above the customary figure.

The purification of solutions is almost always done by working up a certain quantity regularly into bluestone and adding fresh acid to the electrolyte. If the purification requirement is heavy the bluestone department becomes disproportionately large, and consequently copper running high in arsenic is most unwelcome. Antimony and bismuth are seldom present in sufficient quantity to cause trouble. Various chemical methods of purification have been tried with the object of regenerating the electrolyte and returning it to the circulation, but there are few substances that will precipitate arsenic in an acid solution, and further the action of such reagents does not seem reliable, probably due to differences in form of arsenic compunds present at different times. For example, the writer has boiled electrolytes running high in arsenic with metastannic acid[2] and obtained a remarkable cleansing action, and upon other trials found hardly any precipitation.

The insoluble anode slime from which the gold and silver are recovered is very variable in composition, as might be expected, depending on the grade of material being handled. It is chiefly metallic in nature, and a common composition would be as follows:

Ag 40 per cent, Au 2, Cu 25, Se and Te 5, As and Sb 10, Pb, silica, sulphuric acid, etc., 18 per cent.

The presence of so much copper in the slime is objectionable

[1] A paper read before the Franklin Institute of Philadelphia.

[2] U. S. Patent of F. B. Badt.

in the silver refinery process, and must be removed before cupelling the dried slimes to avoid making very rich slags. The other impurities give but little trouble, except possibly tellurium, which requires prolonged furnace treatment to burn it off. The copper is present in very finely divided form, as is shown by experiments in fine screening to reduce the copper contents. Almost all of the copper which will pass a 40-mesh wire screen will also pass a 200-mesh. This would indicate that the coarser screen removes the fine crystals that have dropped from the cathodes, and that the remainder is in the form of a chemical cement. Wohlwill's experiments[3] in-

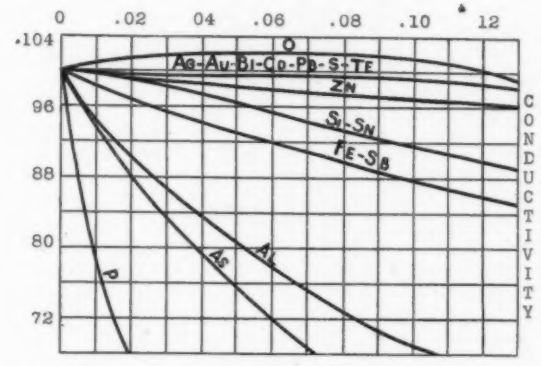


FIG. 1.—INFLUENCE OF IMPURITIES ON ELECTRIC CONDUCTIVITY OF COPPER.

dicate that this is due to the formation of some cuprous sulphate at the anode with subsequent oxidation to cupric sulphate and the liberation of metallic copper:

$$2\dot{Cu} = \dot{Cu}\ddot{} + Cu$$

The amount of cuprous sulphate formed is a problem in chemical equilibrium dependent upon many factors. The copper dust is usually removed by leaching it out in hot concentrated sulphuric acid, taking care not to carry the action too far, as this would result in dissolving some of the silver. If a more rapid reaction is made use of, such as that with ferric or silver sulphates, the copper is dissolved almost immediately, owing to the enormous surface exposed.

The cathode copper is exceedingly pure, usually running about 99.93 per cent copper, with hydrogen as the chief impurity. Objectionable cathode impurities are of two classes—those which depress the electrical conductivity and those which make the metal brittle. Arsenic and antimony represent the first class; tellurium and lead the second. Good cathode copper should show but a few thousandths of a per cent of arsenic and antimony. The writer's experiments have indicated that it takes but 0.0013 per cent of arsenic or 0.0071 per cent of antimony to lower the conductivity 1 per cent. Any conductivity troubles in electrolytic copper can almost invariably be traced to the presence of undue amounts of one or both of these elements.

Impurities of the brittle-making class are very rarely met with, and if present are due to mechanical contamination of the cathode, either in the bath or in the subsequent furnace treatment.

A third class of cathode impurity concerns the refiner, comprising silver and gold. Cathodes usually show from one-tenth to 1 ounce of silver and a trace of gold. This seems to be due entirely to the mechanical fouling of the cathode by particles of anode slime. In fact, it is a question if most of the arsenic and antimony found in the cathodes does not have a similar origin. The slime is very finely divided, and the continual circulation of the electrolyte necessary to prevent polarization maintains a very slight turbidity. These particles are probably electrostatically attracted to the cathode. Fig. 1 shows in a general way the effect of various impurities on the electrical conductivity of copper.[4]

The output of a refining tank depends upon the total current passing through it, the number of electrodes in series, the time the current flows and the electrochemical equivalent. In the present case the theoretical amount per ampere day per pair of electrodes in series is almost precisely an avoirdupois ounce. The amount actually deposited is always less than this, due to chemical solution of the cathode, grounds and short circuits between electrodes. The redissolving of the cathodes will amount in practice to 0.5 to 1.0 per cent of the amount deposited. This action is chiefly at the surface of the bath. In the presence of oxygen, copper is slowly oxidized to cupric sulphate by sulphuric acid.[5] The reaction is quickened by heat, but in so far as the writer's experiments extend, is independent of the composition of the electrolyte. Metallic copper is also slightly soluble in cupric sulphate.[6]

If the tanks are well insulated from the supporting piers, and care is taken to break the circulating pipes carrying the electrolyte from tank to tank, by either rubber sections or miniature waterfalls, the current shunted around the tanks by grounds should not average over 1 per cent of the total. Short circuits between electrodes, caused either by direct contact between anode and cathode or by indirect contact between the electrodes and the tank, will amount to some 5 per cent under best commercial conditions. In this way the net current efficiency is usually from 90 to 95 per cent.

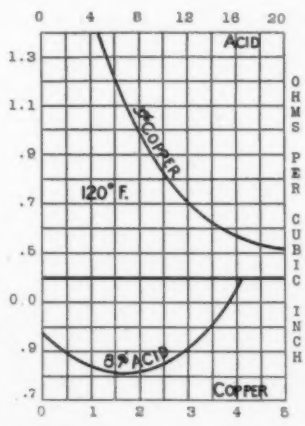


FIG. 2.—SPECIFIC RESISTANCE OF ELECTROLYTES OF VARYING COMPOSITION.

The voltage at the switchboard required to force the current through the tank-house depends upon a number of factors. The resistance is made up of metallic resistances, liquid resistances, contacts and counter e. m. f.

The metallic resistances can be figured on Thomson's law that the cost of power lost should equal the interest on the investment in copper. As the continuous operation gives a load factor of 100 per cent, the rule can be applied without the usual allowances. As regards the investment, the copper can be considered as so much extra metal tied up in the process. Any density under 1000 amps. per square inch will run cool enough.

The liquid resistance of the electrolyte is largely influenced by its chemical composition. Fig. 2 shows the approximate specific resistances of electrolytes carrying varying amounts of copper and free acid. The conductivity of an electrolyte depends upon the number of ions present, the speed of migration and the charge of electricity each carries. The charge carried is a constant for the various compositions, as the valency does not change. The ions concerned are copper, hydrogen and sulphion. Hydrogen is much the swiftest of these, and hence the effect of the free acid present in lowering the resistance.

The number of ions present depends upon the concentration and the degree of dissociation. In this case we have a mix-

[3] *Zeitschrift fur Elektrochemie*, April 23, 1903, p. 311, *et seq.*

[4] See also ELECTROCHEMICAL AND METALLURGICAL INDUSTRY, Vol. III., 1905, p. 314.

[5] *Electrochemist and Metallurgist*, April, 1902, p. 103.

[6] *Zeitschrift fur Elektrochemie*, April 23, 1903, p. 311, *et seq.*

ture of two electrolytes with a common anion, SO_4, and the proportion of one present controls the degree of dissociation of the other. This is shown in the lower curve of Fig. 2, giving the effect of varying the copper contents of the solution. Starting with a fixed percentage of free acid present, additions of copper sulphate at first increase the conductivity, due to the increased number of ions present. After a certain quantity of copper is reached, however, further additions have the reverse effect. This is due to the driving back of the dissociation of the acid by the increased proportion of the SO_4 ions claiming a copper mate in accordance with the laws of equilibrium.

It will be seen from these data that the copper should not exceed 3 per cent at the most, or 12 per cent if figured as bluestone. The acid may advantageously be run up to about

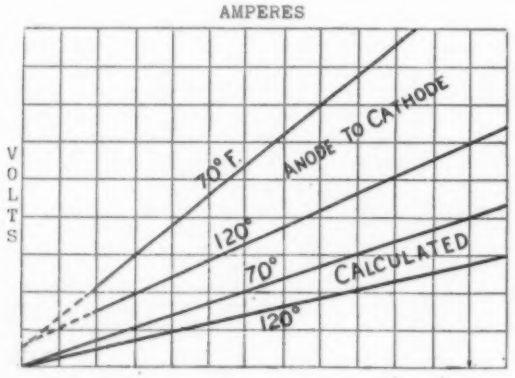


FIG. 3.—VOLT-AMPERE CURVES.

13 per cent. If carried higher, polarization troubles are likely to offset the gain in conductivity. These figures are for pure electrolytes. In practice impurities cause the resistance to be 10 to 15 per cent higher than shown.

Transfer resistance is the name which has been given to a liquid resistance, the nature of which is not fully understood. If we make a series of measurements of the voltage drop between a pair of electrodes at varying current densities, Ohm's law requires that a current-voltage plot should be a straight line. Where this line cuts the ordinate of zero current is a measure of the counter e. m. f. present.

If we analyze the results, however, we shall find that the indicated specific resistance of the electrolyte is higher than it should be, and that the discrepancy is greater the nearer were the electrodes spaced during the measurement. These facts are illustrated in Fig. 3, and indicate a high ohmic resistance near the electrodes. Exploration of the potential gradient between anode and cathode with a potentiometer confirms this, and shows that it exists at both electrodes.[7]

The most probable explanation seems to be that there are minute bubbles of gas in the neighborhood of the electrodes, due to slight generation of hydrogen and oxygen. The phenomena can also be explained by assuming that there is an irreversible polarization present, which is a function of current.[8] The transfer resistance is greatest in the high acid electrolytes and at low temperatures. Its practical effect is to reduce the gain to be expected by spacing electrodes close together and from increasing the acidity of the electrolyte, and to increase the gain to be expected from heating the electrolyte.

The temperature coefficient of electrolytes is large and varies with the temperature. Fig. 4 shows the effect of temperature change on a typical copper refining electrolyte. The practical effect of the change in temperature upon the resistance is rather complex. The transfer resistance exhibits a very large temperature coefficient, while the contacts and metallic conductors are not appreciably affected. The resultant coefficient figured from the switchboard is approximately 0.5 per cent per degree F.

Contact resistances are met with at the joints in the main bars and at the connections between bars and electrodes. The joints in the main bars should be equal in conductivity to the bar itself. This standard can easily be attained if the bars are properly faced. Three or 400 amps. per square inch of bearing area will give no trouble. The contacts between the electrodes and the main bars are very variable. A single contact will run from 0.000005 to 0.0005 ohm, according to the cleanness of the engaging surfaces and the pressure.

Finally, we have a certain amount of counter e. m. f. present, due to the greater concentration of the electrolyte at the anode than at the cathode. This is in general very small—about 0.02 volt per tank in the multiple system. The anode slimes cause a certain amount of polarization, and if very bulky and adherent it may become serious, starting intermittent gasing and making the tank "crazy."

Tank resistance is therefore made up of a number of factors, and, as none of the power applied is absorbed chemically, disregarding the small counter e. m. f., it is possible to make any of these factors as small as desired, and it is a commercial problem to determine the most profitable value for each. A rough summary of the relative values of each in practice is as follows:

	Per Cent.
Metallic resistance	15
Electrolyte, including transfer	60
Contacts	20
Counter e. m. f.	5
	100

The question of what current density to carry is largely one of power cost. Present American practice runs all the way from 12 to 35 amps. per square foot. The steady full load on a large power house gives ideal conditions for the generation of cheap steam power. With high-current density the tank room requires much closer supervision, as there is a greatly increased tendency toward polarization.

It is customary to circulate the electrolyte from tank to tank to maintain uniform composition throughout. If this were not done the heavy liquor from the surface of the anode would form a horizontal layer of increased specific gravity at the bottom of the tank. Different strata would then have different conductivities, crystals of blue vitriol would form on the bottom edge of the electrodes, and the operation of the tank be thoroughly disorganized. The higher the current density the greater this tendency and the more active must be the circulation.

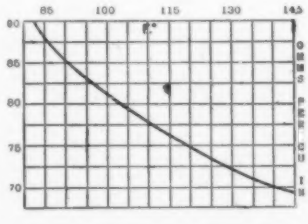


FIG. 4.—EFFECT OF TEMPERATURE.

An excessive circulation tends to stir up the silver mud and results in an increased silver loss in the cathodes. It is safe to say that roughly, the silver contents of the cathodes made at a density of 30 amps. per square foot will be double that of cathodes made at half the density. High-current density also means rougher deposition and necessitates more frequent renewal of the cathodes to maintain the current efficiency. Most of the Eastern refineries run at from 17 to 20 amps. per square foot.

The size of tank is chiefly a matter of construction. The number of electrodes placed in parallel does not seem to bear

[7] Transactions American Electrochemical Society, Vol. VII., p. 51.
[8] Transactions American Electrochemical Society, Vol. VII., p. 33.

any direct relation to the current efficiency. This is probably because low efficiency is caused rather by the condition of the deposit or its tendency to sprout and form trees than by local mechanical troubles between single pairs of electrodes. Sixty electrodes in a single multiple tank give no trouble.

Various dopes have been tried for controlling the character of a deposit. Ammonium sulphate undoubtedly exerts a beneficial effect in encouraging smooth deposits. This may be due to some secondary cathode reaction in which the ammonium radicle is momentarily freed. Ammonium sulphate increases the resistance of the solution, however, by driving back the dissociation of the free sulphuric acid present.

Organic reducing agents, notably gelatin, have marked effect in restraining the crystalline nature of deposits, but are not easily controlled in copper solutions. The peculiar structures sometimes seen at the cathode are doubtless due to the effect of various soluble impurities in the anode. Often a total change in the character of a deposit can be induced by simply lowering or raising the temperature of the electrolyte.

Comparatively little copper is put upon the market in cathode form, although this is an ideal shape from which to make brass and copper castings. The wire bars and ingots never give a conductivity equal to that shown by samples from the cathodes from which they are made. This is partly due to the absorption of some impurities from the furnace lining and products of combustion, and partly to mechanical pocketing of impurities in the cathodes during the electrolytic process. These particles of impurities are associated with nodules, and a smooth part of the cathode is naturally selected as a sample to draw out into wire.

The furnace operation consists in melting down the charge rapidly in large reverberatory furnaces and exposing it to an oxidizing treatment until the bath contains about 6 per cent of cuprous oxide in solution.[9] This exerts a strong scorifying action on such impurities as can be slagged. The metal at this stage exhibits a characteristic fracture, and is called "set" or "dry" copper. Carrying the oxidation further only results in needlessly slagging copper.

The reaction is then changed to a reducing one by means of hydrocarbon gases evolved from green poles thrust beneath the surface of the bath and the copper brought back to "pitch," or when it contains some 0.6 per cent of cuprous oxide, and gives castings the surface of which neither rises nor falls when "setting" in an open mould. The metal in this state develops the best mechanical properties under subsequent treatment. Underpoled copper simply contains an excess of cuprous oxide as an impurity and suffers in both electrical and mechanical properties. Overpoled copper looks like slightly underpoled copper under the microscope. The mechanical properties are satisfactory, but there is a slight decrease in conductivity and castings are bad, due to the expulsion of gases as the metal sets. An overpoled bath is, however, in a very unstable condition, and it is usual in such a case to start at the beginning of the refining operation and oxidize the metal to set copper again. The chemical reasons for these facts are not fully understood. The fact that molten copper is so sensitive chemically to its surroundings, and that it chills so readily, due to its high thermal conductivity, makes it a difficult metal to handle.

This paper has been written from the point of view of the multiple system of refining. The main points of difference between this system and the series system are in power cost, compactness and cost of preparing anodes. The power required is practically half as much again in the multiple tank. The series tank has relatively no contacts or conducting bars, and the electrodes are very close together, the anodes being thin, even plates. To produce such anodes they must be either rolled or specially hand-cast, and the grade of material used must be good. The interest on the metal tied up in process and on the investment in plant is less in the series system. The series system requires no starting sheets, but much closer supervision to keep the quality of the cathodes up. As lead-lined tanks cannot be used in series work, due to the relatively high voltages used, tank maintenance becomes an important item. The fact that large refineries on both systems are being satisfactorily operated bears witness to the close balancing of the pros and cons in each case, although much more material is refined by the multiple than by the series process.

[9] Transactions American Institute Mining Engineers, Vol. XXXIV., p. 671.

R. Threlfall on Electrochemical Theory.

In his recent presidential address to the Birmingham section of the (Brit.) Institute of Electrical Engineers, R. Threlfall made the following remarks:

"As the electrochemical industry rests ultimately upon electrochemical theory, it should be my duty to refer to any advance in our knowledge of the general mechanism of electrolysis. I say 'should be,' because so far as I can judge no very definite advance has been made for several years. It is quite possible, however, that such progress has really been made, but has been buried among those portentious papers which, unfortunately, are so common in electrochemical literature.

"The most pressing want at the moment among laboratory electrochemists is a sense of humor in those who contribute accounts of their work to the various journals. Many of these papers appear to have been written with the idea that people interested in the subject enjoy reading for its own sake, and actually prefer fifty pages to five. I do not know how it may be with those who are exclusively employed in developing the laboratory side of the subject, but I am sure that I shall have many sympathizers with my opinion that if electrochemists would study the art of brevity more than they do, a large number of other people would have a better knowledge of the merits of their discoveries.

"It is a thousand pities that the subject of electrochemistry owes so little to French chemists—had it been otherwise we should no doubt have had a standard of exposition, which would have reduced the volume of the literature in the ratio of, say, 10 to 1. Seriously, the exuberant prolixity of physical chemists is a grave and serious drawback to the study of the subject, for it makes it impossible for anyone to keep abreast of the work unless he rigidly confines himself to a small branch of the science.

"To pass on. I am afraid we must admit that the high hopes exhibited by the preliminary successes of the dissociation theory, say, ten years ago, have ended in disappointment. Those of us who can remember the dreary array of uncoordinated and superficial experiments which formed the subject of electrochemistry in the latter part of the last century, will easily understand how eagerly a theory was welcomed which promised to reduce all to order and regularity. It did not appear too much to hope that a theory specifically limited to dilute solutions, in which domain it certainly was epoch-making, would soon receive such additions as would fit it for use with everyday solutions.

"No one who has tried to formulate some satisfactory account of electrolytic phenomena in the days before Arrheniua, Ostwald, Nernst and van't Hoff can have any feeling except that of gratitude to those pioneers who appeared to have straightened out a plain path of calculation through the maze of observations.

"Alas! it was not so to be. Further investigation, particularly with solvents other than water and with stronger solutions, has shown that a theory which regards the solvent as having nothing in the way of properties except three dimensions in space is quite unable to cope with the phenomena. The simple ionic hypothesis is now little beyond a cherished

memory of what is doubtless one aspect of the phenomena of electrolytic conduction—predominant in solutions of small concentration.

"I wish I could go so far as to say that the hypothesis in its extreme form is only a memory. Unfortunately, this is not the case, for what was once a good servant has grown in its old age into a bad master. I wonder how many young minds engaged in electrochemical research are being stunted and paralyzed by the fashionable necessity of finding an ionic explanation of the phenomena they encounter?

"Who is not weary of the constant recurrence of chemically abhorrent reactions supposed to occur between ions often invented *ad hoc*, and prompted with all solemnity into equations of equilibrium, and that whatever the strength of the solutions? I have seen cases where ions are apparently manufactured from chemical formulas on the *totidem literis* principle as expounded by Swift in the "Tale of a Tub." For instance, Cl might be split on this system into the ions C and l.

"Not only is considerable ingenuity misapplied in the determination to have an explanation of electrochemcial phenomena limited by the dissociation theory at any cost, but the real meaning of the experiments is apt to be masked in the process, and the progress of inquiry arrested by the stifling of curiosity incident on a happy conjunction of gratuitous ions. This is much to be regretted, for I suppose everybody who has worked at these subjects for any number of years must have come to the conclusion that electrochemical phenomena are mainly chemical, and that their elucidation depends rather on the good old plan of close observation and accurate analysis than on dexterity with a pen and paper.

"The crying experimental need of the moment is to find a method of separating and accumulating the layer of electrolyte which is within molecular 'striking distance' of the electrode. Perhaps some kind of minutely porous electrode through which the electrolyte can be drawn at a rate proportional to the current density, or some fortunate discovery in the domain of membranes used as electrodes, may supply us with the all-important instrument of investigation.

"Mr. W. D. Bancroft, in a paper before the American Electrochemical Society (Electrochemical and Metallurgical Industry, 1905, Vol. III., p. 370), has given many illustrations of the application of pure chemistry to electrochemical phenomena, and has, in fact, anticipated much of what I had intended to say on this occasion. In view of this paper, I will only say here that the complexity of electrochemical phenomena is such that a good chemist may be profitably employed for years in elucidating the all-essential details of the chemical reactions occurring at the electrodes between intermediate products of a single electrolysis, and till this is adequately performed no theorizing is of any lasting importance.

"It is no use to be satisfied with the remark that such and such a reaction is an 'oxidation' or a 'reduction' process, or that this or that effect is due to 'over-voltage"; what is wanted is the purely chemical detail free from the ambiguity of cant phrases.

"An investigator starting on such researches as are indicated above will do well to make sure that 'indifferent' electrodes are really indifferent and not catalytic agents. The discovery by Luther and Brislee (*Zeitschrift für Physikalische Chemie*, Vol. XLV., 216, 1903) of the activity of platinum in certain cases is a matter to be taken into serious consideration, and goes far to suggest an explanation of the disappointing results obtained by many observers who have attempted to apply Nernst's method of curves of current and voltage to everyday electrolysis.

"Although the subject of the conduction of electricity through gases has hardly begun to claim the professional attention of the engineer, it is of so much importance that it cannot be passed over. At the present moment it is no exaggeration to say that vastly more is known of the mechanism of gaseous than of liquid conduction, and it does not require much penetration to foresee that an adequate knowledge of conduction in liquids is at least as likely to come from an extension of the principles obtaining in gaseous conduction as by loading the original ionic theory with additional hypotheses.

"In view of the continuity of the gaseous and liquid states it is hard to believe that some of the properties on which gaseous conduction depends do not pass over to, and persist in, the liquid state. I know of no experiments on gaseous conduction extended over the critical point and continued into the liquid state. With a sufficient range of data covering a sufficient number of substances it is hard to believe that some insight into the mechanics of conduction would not be obtained in this way.

"A corresponding research covering the conduction of solutions with less and less solvent and higher temperatures, till ultimately the pure fused salt is alone in question, would possibly—but less probably—throw light on the whole subject. It would at least be interesting to trace cut how the migration velocities become equalized as we approach the state of fusion conductivity.

"If we consider the case of molten sodium chloride, for instance, I am unable to understand how the rate of migration of the anions and cations could possibly be different, as there is here no opportunity for change of concentration. Unless the mechanism of conduction is entirely different in fused salts from what it is in solutions, it might be argued that differences in migration velocities depend upon the solvent more than upon the anions and cations themselves—a view perfectly consistent with the known fact that in a particular solvent water each anion and cation appears to have a relative velocity independent of the other and more or less constant.

"Some work on migration velocities of a few selected anions and cations extended to a large number of solvents could hardly fail to be illuminating. The material may be actually in existence, but if so, I have failed to come across it."

Other portions of Mr. Threlfall's suggestive address will be dealt with in our next issue.

Electrolytic Bleach and Caustic.

By Geo. B. M. Zerr and Jay M. Whitham.

No electrolytic plant can live unless its operation is successful from a commercial standpoint; by "successful" we mean that after charging power, supplies, labor, supervision, taxes, interest, repairs and depreciation to the electrolytic plant, its product must readily sell so as to yield at least a 15 per cent return on the installation costs.

By the electrolysis of brine solutions bleaching powder and caustic soda are produced. These products are in great demand for bleaching pulps, rags, cotton goods, etc., and for digesting woods, manufacturing soaps, refining mineral oils, softening waters, etc.

Bleaching powder, having 35 per cent available chlorine, sells at about $25 per ton, f. o. b. cars at the factory, as compared with $45 in 1902. This decrease in cost is due to the use of electrolytic processes of production. Caustic soda is now worth about $35 per ton, while in 1900 it cost $50. This decrease is due to the use of electrolysis in its manufacture. The caustic produced by electrolysis cannot only be produced at less cost, but is purer than that produced chemically.

The following notes refer to diaphragm cells for the production of bleach and caustic. A diaphragm cell consists of an inner and an outer compartment separated by a porous diaphragm. In one compartment, generally the inner, is an anode, usually composed of graphitized carbon, and placed in a strong brine solution (sodium chloride). In the outer compartment, against the diaphragm, is a cathode, usually of perforated iron

or steel plate. At the start, the outer compartment contains water or weak brine. The chlorine set free at the anodes is led through vitrified pipes to a tower or towers, where it is absorbed by lime water, producing bleach liquor, or it may be conducted to chlorine chambers, usually made of lead, where it is absorbed by slacked lime, producing bleaching powder. At the cathode the discharged sodium ions produce caustic soda in solution. The most successful diaphragms are now made of asbestos cloth, asbestos board or asbestos paper, or of two of these combined.

These cells must be insulated. Direct current, at about 4 volts per cell, is used, and the current varies usually from 300 to 400 amps. for cells of usual size. A bleach and caustic plant is composed of several cells arranged in series for reducing the voltage of the generator to about 4 volts per cell. Thus, a dynamo operating under 120 volts would supply current for thirty cells in series, provided it delivered from 300 to 400 amps.

Several of these series are arranged in parallel to consume the amperage of the generator. Thus, a 250-kw, 120-volt, 2,000-amp. generator will furnish current for six series, each of thirty cells, operated at 4 volts per cell and at 330 amps. per cell.

The following notes give the results obtained with a 3.3-ton bleach per day plant after three months operation:

The bleach solution made in 24 hours referred to, 35 per cent bleaching powder, was..... 7,619 pounds

The electric current used in the 96 cells was:

Volts	205	
Amperes	796	
The switchboard horse-power made was	220	
The engine horse-power made was	260	
Salt used per day	2.34	tons
Lime used per day	0.83	"

The actual installation costs of this plant were:

Engine	$5,000
Generator	5,175
Condenser pump and condenser	1,600
Foundations	500
Building for engine	900
Piping	1,050
Boilers	4,000
Stokers for boilers	1,000
Boiler house, part chargeable to electrolytic plant	700
Feed pump, part chargeable to electrolytic plant	100
Breeching, part chargeable to electrolytic plant	200
Chimney, part chargeable to electrolytic plant	1,500
Bleach and brine tanks, etc.	1,450
Storage tanks	600
Piping	350
Brine engine	500
Cell room building	4,000
Lime tank	300
Salt house	700
Evaporator (caustic) house	150
Evaporator and pumps	2,500
Wiring and lights	420
Brine pumps	225
Caustic tanks	500
Ninety-six cells	14,400
Cables, electric	500
Switchboard	600
Chlorination towers	350
Concrete flow and tank	530
Total (about)	$50,000

That is, the installation cost of a 3.3-ton bleaching plant was about $15,151 per ton.

The operating costs per year are:

Fixed charges 10 per cent on costs	$5,000
223 boiler-horse-power of steam at $40, cost	8,920
Wages	3,388
Repairs	2,000
Lights	210
Salt	4,619
Lime	1,116
Total	$25,153
Yearly 35 per cent bleach produced 996 tons at $28	27,888
344 tons caustic at $37	12,728
Value of product	$40,616
Yearly saving	15,463

Return on the investment for a soda pulp mill using the bleach and caustic as produced 31 per cent.

For a 7½-ton bleach plant to bleach 50 tons of sulphate pulp per day we get the following data. The installation costs are:

250 cells	$37,500
Evaporating apparatus	3,200
Tanks	3,000
Towers and chlorine mains	700
Small pumps	700
Piping at cells and tanks	1,000
Engine and dynamo	20,000
Wiring and switchboard	3,000
Boilers	7,500
Steam and water pipes	2,500
Chimney and breeching	4,000
Buildings	16,900
Total	$100,000
Installation cost per ton	13,333

The annual operating costs of this 7.5-ton (bleach) plant are:

Steam, 400-boiler horse-power at $40	$16,000
Wages and superintendent	6,168
Fixed charges, 10 per cent on $100,000	10,000
Repairs	4,000
Fuel for evaporating	3,300
Salt, at $6.75 ton	14,749
Lime, at $5.25 ton	4,095
Oils, etc.	1,000
Total	$59,312

The yearly profit is:

2,425 tons bleach at $28	$67,900
974 tons caustic at $30	29,220
Yearly income	$97,120
Yearly profit	37,808

The yearly profit is 38 per cent on the investment.

These estimates are based on the actual operation of the bleach plant just described.

Notes on Electrochemistry and Metallurgy in Great Britain.

(From Our Special Correspondent.)

THE FARADAY SOCIETY MEETING.

The Faraday Society opened its winter session on Oct. 31 with a four-paper evening, Lord Kelvin presiding. There was an exceptionally good attendance of members, two past-presidents of the Institution of Electrical Engineers being present,

together with practically the whole of the Council of the Society. The proceedings began with Prof. Ernest Wilson's paper on "Alternate-Current Electrolysis," which had been previously published in the August issue of the Transactions of the Faraday Society. Prof. Wilson gave a somewhat lengthy lecture on his paper, in connection with which the only defect seemed to be that the electrolytes were not in all cases described with sufficient accuracy, the terms "dilute" and "strong" being somewhat vague.

Lord Kelvin then asked Mr. W. R. Cooper for his paper on "Alternate-Current Electrolysis as Shown by Oscillograph Records," and announced that this and the first paper should be simultaneously discussed. The meeting then followed with keen interest a series of oscillograph records, which showed the effect of polarization in retarding the current wave of an alternating current at low voltage, and some records of an electrolytic rectifier were also shown.

The discussion was opened by Mr. A. P. Trotter, of the Board of Trade, which is *inter alia* the legally constituted protector of the interests of the gas and water companies in regard to corrosion arising from earth currents. The speaker naturally diverted the discussion from the laboratory to outside practical experience, by speaking of the risks of the electrolysis of gas and water pipes by alternating currents. He has found that lead subject to corrosion became encrusted with an insoluble salt, perhaps a carbonate. He thought that one phase in each cycle caused the corrosion, and that the deposit being insoluble, the succeeding phase of the cycle was unable to reverse the condition caused by the first. He had buried two lead pipes, each having an area of 40 square inches, in ordinary moist soil, 4 inches apart, the current passing through being kept at 1 amp. The deposit did not cover the whole of each pipe, but ceased on about one-third of the circumference on the part remote from the adjacent pipe. He had also tried the effect of smaller current densities, and had coated four lead plates with varnish, leaving on each an unvarnished area, the plates being buried in the earth and arranged in series across 100-volt mains, and an alternating current was supplied, the respective current densities in amperes per square inch being $\frac{1}{40}$ $\frac{1}{100}$ $\frac{1}{640}$ $\frac{1}{2560}$ Judged visually the amount of corrosion was proportional to the current density, but no weights had been taken to confirm this, as a scraping off of the carbonate film would have entailed the removal of part of the metallic lead. In view of the fact that the current density was as low as 0.00006 amp. per square centimeter, he was of the opinion that so far as electrolytic corrosion, due to alternating currents, was concerned, there was no such thing as a minimum current density. With regard to lead pipes and lead sheathing generally, if electrolysis did occur through stray currents, the insoluble salt forming on both poles would seal up the fault.

Passing then over to a discussion of direct-current electrolysis, Mr. Trotter regarded all accounts previously published concerning this as unsatisfactory. Perhaps the National Physical Laboratory might investigate the matter. So far as tramways in the United Kingdom were concerned, no electrolysis had been reported during the past twelve years where the regulations laid down by the Board of Trade had been complied with. They must also remember that the character of the soil itself was of supreme importance in regard to the life of both lead and iron, for extensive corrosion often occurred where no tramways existed.

Mr. Alexander Siemens stated he had found, twenty years ago, that alternating currents did dissolve lead pipes placed in the ground, but that no measurements of the action occurring had been made. Mr. James Swinburne, referring to Prof. Wilson's estimate of the energy lost per period, pointed out that the loss of energy could not be purely chemical as these processes were reversible; the loss must, therefore, be due to diffusion, which would naturally mean a loss decreasing with the frequency. Mr. Cooper's curves tended to confirm this view. As to Mr. Trotter's remarks concerning insoluble lead salts, in the early days of accumulator design, Lord Kelvin and others had pointed out some curious phenomena connected with the reduction of lead sulphate. Pure lead sulphate was not reduced, but lead sulphate in connection with lead was reducible so long as crystallization did not occur. He deprecated the suggestion that the National Physical Laboratory should study the electrolysis of lead as singularly unfortunate. If there was anything to which they objected at Teddington it was earth currents in any shape or form. Dr. F. Mollwo Perkin mentioned that Le Blanc confirmed Prof. Wilson's views, that with high frequency practically no corrosion occurred. In some experiments of his own, Dr. Perkin stated that with platinum plates in sulphuric, he had, with alternating currents, obtained what was apparently a colloidal solution of platinum. In alkaline solutions he had found a similar result. In reply to the discussion, both Prof. Wilson and Mr. Cooper waived their rights of verbal reply, deferring this to a communication to the Transactions.

Prof. A. K. Huntingdon then read an abstract of his "Note on the Crystalline Structure of Electrodeposited Copper." The only remark made by way of discussion was a contribution by Mr. J. G. A. Rhodin, who expressed his regret that Prof. Huntingdon had not dealt with the current density employed in the production of the samples examined. He (Mr. Rhodin) suggested that the peculiar crystalline formation to which attention had been drawn, had its parallel in magnetism. If a V-shaped groove was cut in one end of a bar magnet, the adhering filings arranged themselves in such a manner as to show a distinct line of repulsion. Were the lines of crystalline stress shown in the microphotographs due in the first instance to an electrostatic action?

Lord Kelvin then announced that, on the author's suggestion, the fourth paper, by Mr. W. Pollard Digby, on "Some Observations Respecting the Relation of Stability to Electrochemical Efficiency in Hypochlorite Production," in view of the lateness of the hour, would be taken as read. Dr. S. Rideal then stated that his interest in the paper was chiefly chemical. The commercial problem of the electrolytic hypochlorites was that of producing a stable solution with a large conversion of chlorine. Mr. Digby had carried an important subject a decided stage further, and he hoped that the investigations would be continued by the author, and that further communications would be submitted to the Society.

The meeting then closed with a vote of thanks to Lord Kelvin, moved by Mr. Siemens, which was carried with hearty acclamation.

The Financial Side of the Electrolytic Alkali Trade.

Thanks, partly to improved trade conditions and partly also to economies in the process of manufacture, the directors of the Castner Kellner Alkali Co. have been able to declare an interim dividend for the six months ending Sept. 30 last, at the rate of 4 per cent per annum. As a result, the market price of these shares, which in January last were £13.16 to £15.16, are now quoted at £1 to £1.⅜ ex dividend. The condition of their chief rivals—the Electrolytic Alkali Co.—which works the Hargreaves-Bird process, is scarcely so happy despite the trade improvement. Preference dividends have been in arrears, but this year a payment is to be made. The report for the year ending Aug. 31 states that the net profit, after allowing for depreciation, mortgage, debenture interest and expenditure on maintenance of buildings, plant, etc., is £4,746, to which is added £1,374 from last year, making £6,120. The directors propose payment on the cumulative preference shares of one year's dividend, on account of arrears of 7 per cent on all the preference shares issued prior to April, 1902, and at the same rate upon all the preference

shares issued since that date. This will leave £519 to be carried forward. The process continues to work satisfactorily, and there is a good demand for the company's products. The great depression which existed in the market price of bleaching powder during 1902, 1903 and 1904 has continued, though to a less extent during the past year. Towards the close of the year the erection of additional manufacturing plants was continued.

At the recent general meeting, Mr. Hargreaves (one of the directors) opposed the adoption of the report, which criticised the policy of the board, and maintained certain salt plants which the company possessed were not adapted to their requirements. He opposed the nomination of Mr. G. H. Harrison as a new director, but, in spite of the opposition, a five to one majority elected Mr. Harrison. Mr. Hargreaves then announced his own resignation from the board. It seems a pity now that trade prospects are improving that the board could not work amicably together.

THE INSTITUTION OF MINING AND METALLURGY.

The first (or October) meeting of the 1905-06 session was devoted to the first of four papers on the agenda. This was Mr. F. Dietzsch's paper on the "Treatment of Tin-Tungsten-Copper Ores at the Clitters United Mines." The paper in itself was a lengthy one, and being contentious and sweeping in its assertiveness, elicited a vigorous discussion. The system which has become used in this reopening of an abandoned mine for the sake of the tungsten present, is one depending essentially in classification in graduated crushing and electromagnetic separation. The details of working are too lengthy for abstracting in this letter. The paper closed with an attack on Cornish mining methods; an attack keenly resented in several of the speeches and communications received.

The remaining three papers were respectively entitled: "The Computation of Assay Values," by William Crosley; "A Graphic Calculator," by William Crosley, and "Ore Valuation of a Witwatersrand Mine," by E. J. Way, and were held over for discussion at the succeeding meeting.

HYPOCHLORITE PROCESSES.

The registration of the British Hosiery & Electrolyte Bleaching Co., Ltd., marks the advent of another electrolytic hypochlorite process on the market, to compete with chloride of lime prepared by the older chemical or newer electrolytic methods. Apparently the new company proposes to reap its dividends from two spheres, the first being that of certain of the Vogelsang patents, the second being some patents for improved knitting and splicing machines. Why the two should be yoked to the same plow is not clear. Separate organizations would surely be desirable. Existing processes in use in England are three in number. The Hermite installations at Netley and Ipswich are, I understand, still in operation for sewage treatment. The Atkins process (owned by Oxychloride, Ltd.), to the trials of which at Guildford I have alluded, is under consideration for sewage treatment by certain municipalities. The Electrozone process, which now uses the Crawford instead of the Woolf patents, has a factory in the north of England, used for turning out stable solutions for domestic and hospital use. The Poplar Borough Council is considering the installation of a plant for municipal disinfecting work. Quite apart from this, experiments are being, and have been, carried out in regard to the bleaching of paper pulps and textile fabrics. In respect to these, the electrochemical efficiencies are generally satisfactory, but the salt consumption remains very high. To compete effectively with existing conditions in paper mills with chloride of lime, a recovery and reworking of the electrolyte seems advisable. This will mean a certain amount of complication, and mill owners distrust complications which they do not understand.

THE SEVENTH REPORT OF THE ALLOYS RESEARCH COMMITTEE.

The subject of the seventh report of this important body was the properties of a series of iron-nickel-manganese-carbon alloys, and was presented to the Institution of Mechanical Engineers at their meeting on Nov. 17 last. The report itself is impossible for useful abstracting, and is too lengthy—covering, as it will, 103 pages of the proceedings of the Institution without the nine plates of magnificent microphotographs which illustrate it—to reprint. It has been so arranged that any particular property of any one alloy can be referred to with as little loss of time as possible. The actual preparation was carried out at the Hecla Works, Sheffield—it goes without saying that Mr. Hadfield is a member of the committee—and the base of the material used was Swedish charcoal iron of special purity. The percentages of nickel varied from nil to 19.91 per cent, the carbon was fairly constant throughout, being between 0.41 and 0.52 per cent; the manganese (whose constancy in any alloy it is notoriously difficult to maintain) varied between 0.82 and 1.03 per cent. The bars generally showed that an increase in the nickel contents raised the maximum stress but limited the elongation. But to attempt to deal adequately with the report would extend over several letters. The committee have presented a report which epitomizes the properties of these alloys, a report of which every decent scientific library will keep copies, and which every metallurgist worthy of the name will place upon his own shelves.

MARKET QUOTATIONS DURING NOVEMBER.

Prices have weakened in only one direction during the month, ammonia sulphate having receded from £13 to £12.12.6 per ton; but in other cases rises are reported. These include arsenic from £14.17.6 to £15 per ton, copper sulphate from £22.15 to £24.10 per ton. Exceptional firmness characterizes the market for coal-tar products, carbolic acid crystals having risen ½ penny per pound to 6d. and 6¼d. for 34-35 per cent and 39-40 per cent respectively. Crude carbolic acid has risen 2d. per gallon to 1s. 10d. Naphtha has also risen; crude 20 per cent at 120° C. fetching 4d. per gallon, and naphtha solvent 90 per cent at 160° 1s. per gallon. The lead derivatives maintain their prices, and flake litharge fetches £17.5, powder litharge £17.15, red lead £16.15, an increase of 5s. per ton in each case. White lead has risen 10s. to £18 per ton. The potash, soda and sulphur compounds are unchanged.

The metal trades generally are in a very prosperous condition, the rise in regard to copper is a phenomenal one. The price on Oct. 31 was £71.5 per ton. On Nov. 30 the price had risen to £78. A heavy demand is reported from all quarters. Tin has risen from £149.15 to £156.10 per ton, but a small decline is anticipated. Lead has risen from £15.5 to £16.2.6. Hermatite pig iron fell from 70s. at the beginning of the month to 68s. 9d. by the 8th, and recovered to 70s. 9d. by the 16th, and closed at 69s. 9d. Cleveland pig iron has fluctuated slightly, the closing price, 52s. 8d.

The all-round general activity is exceedingly agreeable, and one of the symptoms of improving trade has been a circular from some leading accumulator manufacturers notifying a rise in price.

LONDON, Dec. 6, 1905.

Fixation of Atmospheric Nitrogen.

The problem of the fixation of atmospheric nitrogen is now attracting very considerable attention in Europe.

The "Societa di produtti azotati," in Rome, has finally acquired all patents of Dr. Frank, of Charlottenburg, for the manufacture of calcium cyanamide by the absorption of nitrogen by calcium carbide. (See our Vol. I., p. 423, and Vol. III., p. 79.) The process consists of passing nitrogen gas over powdered calcium carbide preliminarily heated to 1,000° C. When the reaction is started, it continues by itself with very small consumption of energy or fuel. The product thus obtained contains about 20 per cent of nitrogen, and can be used as fertilizer.

The first plant, which will soon start operation, is located at Biano del Orte. Its capacity for manufacture of calcium carbide will eventually be 10,000 hp, of which 3,000 hp will first be installed.

It is also reported that a Norwegian company will take over the installation of the Birkeland-Eyde process, at Arundal, for the production of nitric acid from air. (See our Vol. II., p. 399 and 507, and Vol. III., p. 33.) This plant is at present in operation with a capacity of 3,000 hp, which will be enlarged to 30,000 hp.; it produces calcium nitrate.

Report of the Karlsruhe Meeting of the German Bunsen Society.

By H. Danneel and J. K. Clement.

This concludes the report, the first parts of which were published in Vol. II., pp. 327, 466.

Electrode Potentials.

Ostwald has suggested that the electrolytic potential of the mercury drop electrode (Tropf Elektrode) be taken as zero; the proposition was based on Helmholtz' theory of electrocapillarity. Ostwald also introduced the calomel standard electrode as a practical reference electrode, and gave it the value 0.56 volt.

Nernst showed later on that the Helmholtz theory is somewhat uncertain, and suggested that the potential of the hydrogen standard electrode be taken arbitrarily as zero. He emphasized the uncertainty of our information regarding the absolute zero of potential and the clear chemical meaning which the metal potentials have when they are measured against the hydrogen electrode.

Since then there has been an unfortunate pell-mell in the German chemical literature on the subject. At the instigation of the Bunsen Society's committee on units and measurements, two reports were presented at the meeting on the advantages and disadvantages of both methods of measuring electrode potentials.

Prof. R. Luther, Leipsig, represented the Ostwald school. Which electrode is to be selected for reference electrode? Both the calomel and the hydrogen electrodes are easy to reproduce. The hydrogen electrode possesses the advantage that it can be used in any solution of which the alkaline liter is known. The advantages of the calomel electrode are its greater simplicity, its constant readiness for use, the smaller influence of pressure and temperature, and the equal velocity of migration of the ions present.

What numerical value is to be attached to the calomel normal electrode? For exact data the question becomes irrelevant, and the most rational value would be zero. As a matter of fact there are two values for the potential of the calomel electrode in use: — 0.560 (Ostwald), and — 0.283 volt (Nernst). Prof. Luther pointed out that the hydrogen electrode is also hypothetical. In a solution, in which the concentration of hydrogen ions = 1, the gas laws no longer apply. The speaker discussed the sign of the potentials. It is most expedient to give the positive sign to all electrodes which are positive when compared with the reference electrode.

Dr. F. Krüger, of Göttingen, represented the Nernst side of the controversy. The theoretical zero of potential is of no importance so long as no relation between the solution tension of metals and other properties are known. The absolute zero point is of no more use for a table than any other zero point. The potential drop between different solutions is in most cases negligible compared with the errors of observation. An advantage of the calomel electrode is that the ionic velocities of the electrolyte are equal. But there is an appreciable error when it is used in acid solutions.

The calomel electrode is, therefore, suitable for comparisons in neutral solutions; the hydrogen electrode in acid and alkaline solutions, and especially where an oxidizing or reducing action takes place. The principal advantage of the hydrogen electrode is that it introduces no foreign ions into the solution.

The hydrogen electrode is of great didactic importance in the consideration of oxidation and reduction cells. After considerable discussion the decision was left to the committee on units and measures.

Explosive Antimony.

Prof. E. Cohen, of Utrecht, presented a paper on this subject. By the electrolysis of solutions of $SbCl_3$, or of other antimony haloids, a metal is obtained which explodes when roughly handled; it becomes hot and emits a white vapor. The latter consists of gaseous antimony haloids, which are always deposited by the electrolysis, and form with the metal a solid solution. The heat is produced by the transformation of the metal into another allotropic modification. The explosive metal is obtained only under definite conditions of temperature and concentration.

Crystalline Liquids.

Dr. R. Schenk, of Marburg, spoke on the nature of crystalline liquids. A number of liquids exhibit the phenomena of double refraction and are optically active. Up to the present time twenty-one of them have been found. They belong to the most varied groups of organic compounds, and one of them is inorganic, potassium iodide. On cooling slowly, needle-shaped, uniaxial crystals separate from the melt. On account of the surface tension, the corners of the liquid crystals are rounded. In a magnetic field the drops arrange themselves in certain definite directions. On heating, the crystalline liquids change to the ordinary liquid state. The point of transformation is quite like a melting point; *e. g.*, it is depressed by the addition of a foreign substance. Tamman and Quincke maintain that the liquid crystals are two-phase formations (suspension of crystals or emulsions). The author considers that they belong to a separate state.

Spectrometry for Determinations of Concentration.

Dr. F. Löwe, Jena, presented a paper on new applications of spectometry. The speaker exhibited a new refractometer, made by Zeiss & Co., which permits determinations of the concentration of alcohol with as great accuracy and in much less time than with the pycnometer. Printed descriptions can be obtained from Zeiss & Co., Jena, Germany.

Atomic Weight of Bismuth.

Dr. Gutbier, Erlangen, discussed the atomic weight of bismuth. He found by the oxidation of pure bismuth 208.02, by the reduction of Bi_2O_3 by means of NH_3 and Ag 208.03, and by the determination of the Cl in $BiCl_3$ as AgCl, 208.05.

Ozone.

Prof. Luther, Leipsig, read a paper on ozone. It acts in most cases a divalent oxidizing agent; one molecule O is consumed in oxidation and O_2 is liberated. In a few cases only are all three O molecudes active, viz.: with substances which are oxidizable by O_2.

The valence in any given reaction can be determined with the aid of Nernst's formula, by measuring the e. m. f. of an electrode of inactive material in ozone solutions of varying concentrations. For a ten-fold change in the concentration of ozone the e. m. f. will change 0.058 volts when the ozone is univalent, 0.029 volts when it is divalent. The author found that a ten-fold increase of concentration produced an increase in potential of 0.054 volt on Pt electrodes. Ozone is, therefore, univalent in this reaction. The author does not accept Gräfenberg's view that ozone is 6-valent. Gräfenberg attempts to explain his view by assuming that ozone is 6-valent in gas form only, not in solution. If this be true, Henry's law of absorption does not apply; doubling the gas pressure would produce a 64-fold increase of the concentration in the solution. The author determined the absorption of ozone and found that Henry's law holds.

The author found that the oxidizing potential of ozone in equal concentrations is 0.2 volt lower on iridium electrodes than on smooth platinum electrodes, and the variation of e. m. f. corresponding to a ten-fold change in concentration is 0.027 volt; *i. e.*, ozone is in this case divalent:

$$O_3 + 2\,(-) = O_2 + O''$$

or

$$O_3 + 2\,(-) + 2H^{\cdot} = O_2 + H_2O$$

Where (—) means a negative charge. We might distinguish between a univalent, active and a divalent, passive, ozone; and as is the case with chromium, the reaction and not the substance acted upon may determine the e. m. f.

We should be cautious in interpreting the potential of O_2. This amounts to 1.07 volts on iridium electrodes, and reaches 1.15 volts on platinized platinum.

In the discussion, Prof. Haber said that according to his calculations the e. m. f. of the oxyhydrogen gas battery is probably greater than 1.2 volts. Nernst stated that he had calculated the e. m. f. of the gas battery from the dissociation of CO_2 of water vapor, and of HCl. Its value can be safely placed at 1.2207.

OXIDATION OF PALLADIUM.

A paper on this subject was presented by Dr. L. Wöhler. Palladium sinters at 875° and then oxidizes rapidly. Palladium foil becomes green at 830°. The author has determined the dissociation constants and the heat of formation of the palladium oxidation. The heat of formation is 24 calories. According to his experiments, palladium suboxide does not exist. Platinum oxidizes at temperatures above 400° only. Pt — oxide decomposes at 560°. For this reason the oxidation of platinum has often been overlooked. Oxidized Pt contains 70 per cent Pt — monoxide and 30 per cent Pt — dioxide. After repeated oxidation and decomposition the Pt deteriorates; its capacity for O decreases, *i. e.*, the decomposition of the oxide is more rapid than the formation.

PRODUCTION BY LIGHT OF A REVERSIBLE REACTION.

Prof. F. Haber spoke on the precipitation of ferrous ions in aqueous solutions of potassium ferrocyanide, describing a typical case of the production by light of a reversible reaction in a homogeneous system. The formation of potassium ferricyanide from potassium ferrocyanide and the green coloring of the ferrous salt, under the influence of light, is non-reversible. On the other hand, the action of light on alkaline solutions of potassium ferrocyanide increases the concentration of ferrous ions to such an extent that they may be detected by reactions which do not take place when light is excluded. The dissociation of potassium ferrocyanide increases in the light and decreases in the dark. In the light, iron can be precipitated from it as iron sulphide; or, when O_2 is passed through the solution, as ferric hydroxide. The precipitation does not take place in the dark. The author exhibited an apparatus containing an "Uviol lamp," in which ferrous ions were precipitated by the usual reagents. The more alkaline the solution the easier it is for the reaction to take place.

Haber's theory is that the light rays are unequally absorbed by the various substances concerned. He assumes that the undissociated, complex ions absorb more than the Fe and CN′ ions combined. The absorbed light produces further dissociation until the amount of energy absorbed by complex and by simple ions is the same.

On account of the disturbance of the equilibrium the simple ions reunite with evolution of heat, light separates them again, and so on; *i. e.*, the solution is a machine for transforming radiant energy into heat. The amount of energy supplied by sunlight in 1 second, to a surface of 1 sq. cm. area, is the product of the pressure of light (4×10^{-5} gr. per sq. cm.) times the velocity of light (3×10^{10} cm. per sec.), or 1.2×10^{5} gr. cm. per cubic cm.

A surface of 1 sq. cm. area would receive 12,000 calories per hour. Only a small part of this is used, as the amount of dissociation necessary to give a reaction of ferro-ions is small.

MAGNETIC COMPOUNDS FROM NON-MAGNETIC ELEMENTS.

Dr. E. Wedekind spoke on magnetic compounds from non-magnetic elements. The author found that the manganese borides, MnB and MnB_2, which he had prepared by the Goldschmidt process, are magnetic, both in compact form and in the form of a black crystalline powder. Arsenide of manganese is non-magnetic. Manganese bismuthide is magnetic, although bismuth is known to be strongly diamagnetic. That these are compounds and not alloys is shown by the fact that the excess of either component can be removed in a stream of chlorine without the compound decomposing. The magnetism is permanent. A glass tube, filled with the magnetized powder and suspended by a thread, comes to rest with its axis in the magnetic meridian. Shaking produces demagnetization.

CONDUCTION IN METALS.

Dr. Max Reinganum spoke on the electrochemical equivalent and the electric conduction in metals. It is interesting to find an indication that the Faraday principle of electrolysis applies also to metallic conduction.

The relation of electric conductivity k to heat conductivity h is expressed by the equation

$$\frac{k}{h} = \frac{1}{2}\,\frac{mu^2}{eT}$$

where u is the mean molecular velocity, e the charge and T the absolute temperature. The term $\frac{mu^2}{e}$ can be calculated directly for electrolytes, and for metallic conductors it can be calculated from k ÷ h. The two values are identical. For the particles which carry the current in metallic conduction, the relation of kinetic energy to charge is the same as for a univalent ion. If the kinetic energy of both is the same, the charge of a particle in metallic conduction is the same as the charge of a univalent ion. The author calculated that the charge of an atom of copper is equal to the charge of two free ions.

SYNOPSIS OF PERIODICAL LITERATURE.

A Summary of Articles Appearing in American and Foreign Periodicals.

INDUSTRIAL ELECTROCHEMISTRY.

Tin Refining.—In "Elektrochem. Zeitschrift" of 1905, pages 136 to 140 and 161 to 164, Dr. Hans Mennicke further discusses the electrolytic refining of tin, basing his experiments and calculations on Betts' process for the electrolytic refining of lead. It seems possible that he has overlooked one thing in applying the methods of Betts' process to tin refining, and that is that fluosilisic acid is used for lead refining, not because it has inherent advantages over other strong acids, except the solubility of the lead salt.

Very probably the author would have gotten practically the same results with tin sulphate that he has with tin fluosilicate, and would have had a more convenient solution to prepare.

The most troublesome impurities in tin are antimony, copper, bismuth, arsenic and silver. The treatment of electrolytic tin slime should be cheaper than the treatment of lead slime, as a mere treatment with sulphuric or nitric acid will dissolve out most of the impurity. Theoretically the electrolytic refining of tin should succeed, but the author questions whether small-scale experiments would be capable of demonstrating this. Experiment shows that the loss of tin in the anode slime is greater than the corresponding loss of lead. The cathode tin is also found to contain lead, unless the anodes contain very little lead. The author does not fear that cobalt, nickel, iron and zinc will interfere with commercial success. "Work-tin" usually contains iron, lead, copper, bismuth, silver, antimony, arsenic, beside zinc and tungsten. Almost all bismuth, silver, copper, antimony, arsenic and tungsten remain in the slime. Success will depend not only on the process but on the grade of raw tin, which varies widely.

Usually the author used solutions containing about 10 per cent tin and 10 per cent free fluosilisic acid, with an e. m. f. averaging 0.4 volt, sometimes as high as 3 volts. The current density averaged 1 amp. per square decimeter (9 amps. per square foot). No gelatine or albumen was ever added. The temperature was about 20° C. The separation of electrodes was usually 5 cm., sometimes 7.5 cm. Large quantities of iron, zinc, nickel and cobalt made no trouble in the solutions. Tin oxide was found to be insoluble in fluosilisic acid. Freshly precipitated stannous hydrate was used to prepare the solution. Better results were obtained with raw tin than with tin alloys. The cathode deposits were extremely solid and tough. The lower the voltage the finer the tin crystals. With a cold electrolyte the author successfully detinned tin cuttings, producing a solid cathode deposit, which would not, however, be a practicable process for commercial work.

The author experimented with tin-lead alloys as anode with the same conditions of current, etc., as above. The anode was strongly but evenly attacked, and the cathode metal, especially on the start, was good. The electrolyte, however, clouded, and whitish deposits of lead fluoride formed on the anodes, showing the presence of HF in the electrolyte. The cathode deposit gradually became spongy, but consisted of absolutely pure tin. The author states as a conclusion that the presence of H_2SiF_6 in the solution will make a solid tin deposit if lead is absent. The current yield was found to be about 90 per cent, but grows less as the process is carried further. Perhaps the author's solutions also contained tin difluoride (from an excess of HF in the H_2SiF_6 used in making the solution), as appears from the observed formation of lead fluoride on anodes of solder. Tin difluoride should be an excellent salt for electrolytic refining, as basic salts would not tend to separate.

Electrolytic Nickel.—In our first volume a great amount of information was given concerning electrolytic nickel. Two processes were formerly used. The Browne process, at Cleveland, for the treatment of copper-nickel matte of the Canadian Copper Co., and the Thum process, at the Balbach works in Newark, for refining nickel shipped from the Orford Copper Co. The former process was discontinued when the works of the Canadian Copper Co. were bought by the "Nickel Trust," but this process will be put again into operation, when the new electric power transmission of the Canadian Copper Co. to Copper Cliff is completed. The Balbach works stopped operation of the Thum process when the orders of the Orford Copper Co. for refining nickel stopped coming in. According to the November issue of the "Brass World" electrolytic nickel refining has now been taken up by the Orford Copper Co. "The nickel is deposited by means of the electric current upon a sheet of nickel which has previously been coated with graphite, to prevent the adhesion of the deposit to the cathode surface. When the requisite thickness has been obtained the deposit is removed from the cathode plate and is ready for use. The cathode plates of nickel, as now produced, have the dimensions of 3 x 4 feet and about ¼ inch in diameter. The average purity is 99.5 per cent. It is absolutely free from carbon. Electrolytic nickel is in special demand by manufacturers of german silver. It is mentioned that the electrolytic nickel plates are so tough that they must be cut by means of power shears; this is a disadvantage. The surface is "wart-like." "While the process is a secret one, we understand that a solution of chloride of nickel is used as electrotlyte. By this method it is possible to prevent the contamination of electrolytic nickel with sulphur, as would be the case were a sulphate solution used as the electrolyte." A chloride solution is also used in the Browne process.

Production of Copper Salts.—In "L' Industrie Electro-Chimique," of July and August, the following process of E. Campagne for the production of copper salts is described. If a solution of sodium sulphate is electrolyzed between copper electrodes, copper goes into the solution from the anode as copper sulphate, and sodium hydroxide is formed at the cathode with evolution of hydrogen. The former two react together and produce cupric oxide and sodium sulphate. The cupric oxide sinks to the bottom in form of a powder, and, being soluble in acids, it may be used as a very convenient starting material for the production of various copper salts. Some precautions which must be taken are mentioned, and the industrial application of the process for the production of copper sulphate and copper acetate are described.

Metallic Calcium.—For some time metallic calcium has been on the market in Germany, being made by the Elektrochemische Werke, Bitterfeld, according to the patents of Rathenau. The principal feature of this patent was the gradual rise of the metallic calcium cathode during electrolysis, so as to prevent the calcium that is being deposited from being redissolved in the electrolyte. Essentially the same method (although with differently designed apparatus) was used by J. H. Goodwin (our Vol. III., p. 80), whose complete paper may be found in the November issue of the "Journal of the American Chemical Society." Another experimental investigation of the same process was made by P. Woehler, who describes his results in the "Zeit. f. Elektrochemie," Sept. 8. The author used an electrolyte consisting of 100 parts of calcium chloride and 17 parts of calcium fluoride. The melting point is 660° C. (while the melting point of pure calcium chloride is 780° C.). The melting point of metallic calcium is 800° C. The author maintained the electrolyte at a temperature between 665° and 680° C., the highest temperature being used at the cathode, so that when the calcium rod is raised out of the fused bath the fused electrolyte adhering to it is of sufficient fluidity to flow down into the bath. Only in this way a pure metallic calcium rod can be obtained. The author used 40 amps. at 38 volts with a cathodic current density of 100 amps. per square centimeter, and thus produced calcium rods of any length at will. The process runs well and with a high efficiency as long as one uses a fresh neutral electrolyte. But the longer the electrolyte has been in use, the poorer becomes the output. The cathodic current density is of little influence. The operation was equally favorable when at a constant current of 40 amps. The current density was gradually raised from 50 to 250 amps. per square centimeter (by diminishing the

cathode diameter from 10 to 4.5 mm.). The anodic current density must not be too low, since otherwise the electrolyte freezes around the anode and the chlorine gas accumulates through the whole electrolyte; neither must the anodic current density be too high (above 5.6 amps. per square centimeter), since otherwise a great many small arcs are formed between anode and electrolyte, with a large increase of e. m. f. With a fresh electrolyte the ampere-hour efficiency was found to be 82 per cent. "If the kw-hour is charged at 1.25 cents, the cost of electrical energy for the production of 1 kilogram of metallic calcium—namely, 62.12 kw-hours—becomes $0.78. The market price is $4.50 per kilogram." The specific weight was determined as 1.51.

Aluminium.—A statistical review of the aluminium review in Europe is given by R. Pitaval in the "Journal de l' Electrolyse" of Oct. 15 and Nov. 1. Although the Heroult patents have now run out, new producers have not entered the field; but the old companies have increased their plants and are dominating the bauxite supply. There are four large European companies producing aluminium: the Societe Electrometallurgique Francaise, producing 1,000 tons per year (Froges, La Praz, St. Michel); Societe des Produits Chimiques d' Alais, 600 tons; the Aluminium Industrie A. G., 3,500 tons (Neuhausen, Rheinfelden, Gastein); the British Aluminium Co., 600 tons.

Reduction of Metallic Oxides by Aluminium Carbide.—The only commercially successful method of producing aluminium is by electrolysis, and all attempts of making aluminium in the electric furnace by reduction of aluminium with carbon have been unsuccessful. Although it is possible to prepare alloys of aluminium by reduction of the oxide by carbon in presence of such metals as copper and iron, yet when it is attempted to obtain the pure metal by direct reduction, the product is almost exclusively aluminium carbide. The behavior of aluminium carbide when heated in contact with metals and metallic oxides is, therefore, of considerable importance to the metallurgy of aluminium, and a series of experiments made on this problem by J. N. Pring, at Manchester University, and published in the "Transactions of the (Brit.) Chemical Society," 1905, Vol. LXXXVII., pages 1530 to 1540, contain much that is of interest. To prepare aluminium carbide the author used the method of Moissan, which consists in heating aluminium contained in a carbon crucible in his ordinary arc type of furnace. Some figures are given on power consumption and yield. It appears that the aluminium carbide formed results chiefly from the action of carbon monoxide on aluminium. The author studied the reactions of aluminium carbide with oxides up to about 1,200° in a wind furnace, first without a flux and then in presence of cryolite as a flux. A further series of experiments was made at higher temperatures in an electric resistance furnace.

The chief results are as follows: The work here recorded seems satisfactorily to explain the reactions which occur between aluminium carbide and metallic oxides and metals. Up to about 1,400° the carbide behaves as a strong reducing agent, but both aluminium and carbon are simultaneously oxidized even when the carbide is in excess. Thus, under these conditions no separation of aluminium or of carbon can be detected. For instance, aluminium carbide interacting with copper oxide produces metallic copper and carbon dioxide, together with small quantities of carbon monoxide. A similar behavior is noticed when the reactions are brought about in the mass of a flux so as to facilitate the agglomeration of the reduced metal. At higher temperatures, however, selective reduction begins to be apparent, the reduction being more and more brought about by the carbon of the carbide, with a result that alloys of aluminium and the reduced metal are obtained, the percentage of aluminium increasing the higher the temperature of reaction.

In the case of copper, the percentage of aluminium in the alloy seems to be limited by the volatilization of aluminium. Copper alloys were obtained containing up to 28 per cent of aluminium, whereas the equation

$$3CuO + Al_4C_3 = 4Al,3Cu + 3CO$$

demands an alloy containing 36 per cent of aluminium.

In the case of iron, an alloy was obtained containing 46.7 per cent of aluminium, or subtracting the amount of free carbon, 49.6 per cent of aluminium. This corresponds to the equation

$$Fe_2O_3 + Al_4C_3 = 2Fe,4Al + 3CO,$$

which demands an alloy containing 49.2 per cent of aluminium. Any excess of oxide used in the reaction resulted in oxidation of the aluminium of the alloy. When the reaction between aluminium carbide and iron oxide was brought about in presence of a bath of molten iron at a high temperature, alloys were also obtained in which more than 90 per cent of the aluminium of the carbide used had been set free and taken up by the iron.

Calcium carbide exhibits, in a smaller degree, a behavior similar to that of aluminium carbide in the relative affinities of the calcium and the carbon for oxygen at high temperatures. Reactions between lead oxide and excess of molten calcium carbide gave an alloy containing 2.6 per cent of calcium.

These results are explained by the fact that at high temperatures alumina can be reduced by carbon, and the following equation, which at comparatively low temperatures is known to go in the direction from left to right, would, at high temperatures, apparently be reversed and occur in the opposite direction:

$$6Al + 3CO \rightleftarrows Al_4C_3 + Al_2O_3$$

Owing to the evolution of heat in these reactions between oxides and aluminium carbide it was not possible to fix or estimate the temperature at which reaction actually took place. Aluminium carbide reacts with copper at a temperature below the melting point of platinum, and with iron just above this temperature, to form an aluminium alloy with liberation of free carbon. At higher temperatures the reaction takes place with violence and is complete.

Calcium Carbide.—In the "Journal de l' Electrolyse," R Pitaval gives a summary of progress in calcium carbide manufacture in France during recent years. Instead of arc furnaces resistance furnaces are now used. While one hesitated formerly to use a higher furnace capacity than 300 hp., now the resistance furnaces of the Clavaux plant have a capacity of 500 hp. each, and in the Darfo works (Froges de Veltri) furnaces with two electrodes and of 1,200-hp. capacity will be installed. Formerly the usual voltage was 60, now the tendency is towards 40 or 30 volts. The mean consumption of carbon electrodes is now 50 to 60 kilograms per ton of carbide, but with the latest types of furnaces this may be reduced to 20 kilograms. The greatest care is now taken to use pure and dried raw materials, anthracite and lime, at least 95 per cent pure.

Calcium Carbide and Acetylene.—An interesting paper, which has not yet been noticed in these columns, may be found in the "American Gas Light Journal" of July 10, 1905. The author is J. B. Morehead. He first gave an historical sketch, especially of the experimental work of the Wilson Aluminium Co., in North Carolina. Their object was to make aluminium by reducing alumina by means of metallic calcium, and they intended to make the metallic calcium by reducing lime with carbon. Lime and coal-tar were mixed and put in an electric furnace. After

a run, which lasted several hours, on this mixture a sample was taken out of the furnace, and in accordance with the usual custom was placed in water in order to cool it for an analysis. Large volumes of gas were given off, and at first it was thought that the substance was metallic calcium and that the gas given off was hydrogen, but upon lighting it it was found to burn with a heavy yellow flame and to give off quantities of soot, which proved to be some rich hydrocarbon gas and not hydrogen. Subsequent analysis of the substance proved it to be calcium carbide, and the gas was pronounced acetylene. This first experiment was made on May 4, 1892. The author then gave a review of the production and properties of commercial acetylene. The principal reasons for the success of acetylene in the lighting field are the low first cost of the plant, the simplicity of production, the small cost of maintenance and repairs, and the economy of the light furnished. The candle-power of acetylene light is so high that only one-tenth of the volume of acetylene is required to produce a given candle-power, as compared with the volume necessary when other gases are used. This means that in a town where ordinary illuminating gas would require a holder of 10,000 cubic feet capacity to supply one day's requirements, a holder of only 1,000 cubic feet is necessary if acetylene is used. The same reasoning applies to the size of the mains. (Acetylene is generally sold by 100 cubic feet, not by the 1,000, and the price ranges from $1 to $1.50 per 100.) The cost of producing acetylene does not depend upon the quantity of the gas generated, as no fuel or materials other than carbide and water are required. Acetylene may be produced in small quantities at quite as low a cost as it can be made in large volumes. The number of town lighting plants in this country was 4 in 1898, 8 in 1899, 30 in 1900, 39 in 1901, 60 in 1902 and 202 in 1904. In addition there are now in operation a very large number of isolated plants.

Welding by Means of Acetylene.—In the "Jour. f. Gasbeleuchtung," of Dec. 2, S. Traubel advocates the use of the acetylene-oxygen flame for autogenous welding of iron and steel. It is claimed that the cost is only one-third that of other autogenous welding methods and that the joints are always clean. He gives some data on the Fouche system, in which the pressure of the acetylene supplied to the burner is not more than 20 mm. column of water. One cubic meter of acetylene, weighing 1.165 kg., gives 12,900 calories (while 1 cubic meter of hydrogen gives only 2,580 calories in the oxyhydrogen flame). Theoretically, 2½ parts of oxygen are required for 1 part of acetylene, but in practice an excess of acetylene is used; the usual figures are 1 part of acetylene for 1.7 part of oxygen, parts meaning parts by volume. The acetylene-oxygen flame has in its center a small blue cone, the point of which has a temperature of about 3,000°, while around the cone there is an atmosphere of carbon dioxide and hydrogen, so that the iron or steel is welded in a reducing atmosphere. The acetylene-oxygen flame is smaller, more quiet and hotter than the oxyhydrogen flame. Some data are given on the cost of welding sheets of thicknesses of 1 to 9 mm. It is stated that the process is considerably used in France and Belgium. In connection with this subject the following notes from an address of R. Threlfall (London "Electrician," Dec. 8) are interesting: "At the recent exhibition at Liege there was a display of oxy-acetylene blow-pipes of large size, intended to compete with thermit for repairing wrought iron. It is very probable that with silica tubes and rods (made inside carbon tubes from sand) and suitable oxyacetylene blow-pipes it will be possible, even easy, to make any kind of apparatus, large or small, out of opaque silica. The method should also be capable of generalization for the fusion of those oxides which are reduced with difficulty by carbon; **i. e.,** zirconia, magnesia and the alkaline earths and the oxides of vanadium and titanium, provided they are presented in the right state of fineness."

Electrolytic Zinc Plating versus the Hot Dip.—"Dingler's Polyt. Jour." of Nov. 25 contains an account by I. Szirmay of comparative tests of iron and steel ware, zinc plated by electrolysis and by the hot dip. Both mechanical and chemical tests were made. The arrangement for the chemical tests is shown in Fig. 1. The zinc-plated iron plates and wires **e** are suspended within a vessel, the walls of which can be filled with hot or cold water so as to vary the temperature. The interior of the vessel was filled with air containing different proportions of sulphurous acid, carbon dioxide, moisture and steam. By alternately filling the walls of the vessel with hot and cold water the temperature was varied between the 6° and 45° C., resulting in considerable condensation on the test plates and wires. He found that during the exposition the plates covered with zinc by the hot dip became black, and that the hot dip does protect iron and steel ware against atmospheric influences. While in the plating of articles by the hot dip relatively large quantities of zinc are consumed on account of the impurity of zinc, if sufficient protection against rusting shall be obtained, much less zinc is required in the electrolytic method on account of the purity of the deposit. The large quantity of zinc and the non-uniformity of the deposit with the hot dip result in poor adherence. When sheets, tubes and wires undergo mechanical wear and tear, the zinc coating suffers, and premature rusting occurs.

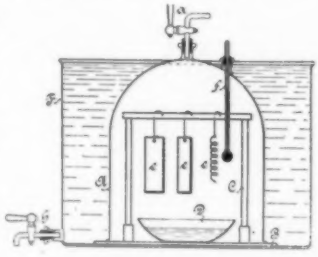


FIG. 1.—TESTING ZINC COATINGS.

Theoretical and Experimental.

Electrolytic Regeneration of Chromic Acid.—E. Mueller and M. Soller ("Zeit. f. Elektrochemie," Dec. 1) has studied the influence of the anode material on the electrolytic production of chromic acid from sulphate. With a solution of pure chrome alum in 1-normal sulphuric acid there is practically no formation of chromic acid at a polished platinum anode. But the least traces of a dissolved lead salt accelerate the reaction extremely on account of the deposition of lead peroxide on the anode. Small quantities of chlorine ions also favor the reaction. With a lead peroxide anode the formation of chromic acid goes on very satisfactorily, while on a platinized platinum anode the ampere-hour efficiency is about one-third that at a lead peroxide anode. The good results obtained with lead peroxide are believed to be due to catalytic action, and are thought to be related to the fact that PbO_2 can react chemically with the chromium ions.

Passive State.—In the "Zeit. f. Elektrochemie," Dec. 1, C. Fredenhagen gives some points in favor of his view that the passive state of metals may be explained by a "charge" of the surface of the metal with a gas—whether the gas is assumed to be dissolved in the metal at the surface or whether there is an adhering surface film of gas or whether there is a combination of the two. The author believes that all facts which may be explained by the assumption of an oxide film on the surface are also explainable by his assumption, but that his assumption applies to more cases.

Generator Gas Cell.—A paper by F. Haber and A. Moser

in the "Zeit. f. Elektrochemie," Sept. 8, gives an interesting account of a theoretical and experimental investigation of what is commonly called the carbon cell. At a temperature of about 500° C. the e. m. f. of the carbon-oxygen cell and also of the carbon monoxide-oxygen cell (or, as the authors say, the generator gas cell), is near 1 volt, according to the theory (i. e., calculated from the free energy of the reaction). It is necessary to use an elevated temperature since at ordinary temperature the speed of the reaction between carbon and atmospheric oxygen is very low. The choice of a proper electrolyte at 500° C. would offer some difficulties, but since the authors were not after a commercial carbon cell giving strong currents, but only intended to measure the e. m. f. of such cells under varying conditions for the sake of comparison with the theory, they could use heated solid glass as electrolyte, which proved very satisfactory. (Concerning solid electrolytes see Haber and Tolloczko, our Vol. III., p. 99.) The construction of the apparatus, the theory of the subject, and the results obtained in the tests are given in detail. The results of the theory were fully confirmed at temperatures somewhat above and below 500° C. By using concentrated carbon monoxide (instead of a mixture of monoxide and dioxide) the reaction is changed from that of the generator gas cell into that of the carbon cell. The application of hot glass as electrolyte permits the realization of the oxygen-hydrogen gas cell at high temperatures.

IRON AND STEEL.

Carbon Deposition.—Dr. F. Zimmerman describes in "Stahl und Eisen" for July 1 an investigation on the action of carbon monoxide upon metallic oxides and metals. He brought the gas into contact with these materials at the temperatures of boiling diphenylamine (320° C.), mercury (360° C.), sulphur (445° C.) and phosphorus sulphide (508°). Neither NiO, CoO, FeO or Fe^2O^3 acted as inciters or catalysors to produce deposition of carbon at any of these temperatures. Metallic nickel was very active, the spongy metal deposited on pumice causing very rapid deposition of carbon, with evolution of heat, without the nickel being oxidized. Cobalt behaved similarly. Equilibrium was attained in about 7 hours. Pumice impregnated with metallic iron behaved very differently. Up to 400° the reaction was similar to nickel and cobalt, but much slower; at 445° and 508° the reaction was very rapid, but in the sense of the equation

$$Fe + CO = FeO + C$$

the reaction proceeding so far that gas pressures as low as 50 millimeters were produced in the apparatus. The author believes that the iron really first promotes the reaction

$$2CO + Fe = CO^2 + C + Fe$$

by catalytic action, and then is oxydized by the CO^2:

$$Fe + CO^2 = CO + FeO,$$

the CO thus formed repeating the cycle, until almost all gas has disappeared. The facts thus disclosed should have a considerable influence in determining the nature of the reactions in the upper part of a blast furnace.

High-Speed Steel.—Ledebur contributes a short article to "Stahl und Eisen," July 1, bringing forward the views of one of his students, Otto A. Böhler, on the question of the nature of air-hardening high-tungsten steel. The gist of the view is, that when this steel is cooling the Martensite which is present at a high temperature does not split up into cementite and ferrite (the mixture called perlite), but the presence of the tungsten lowers the critical temperature at which such change takes place below the ordinary temperature, so that the carbon all remains behind as hardening carbon. It is to be regretted that Ledebur published such rather crude views without having given them a "crux experimentis" in the shape of subjecting such air-hardened steel to abnormally low temperatures, to see if (like the magnetic reversability of high nickel steels) the change spoken of as being deferred really will take place at a very low temperature. If such a test were made we would know whether Böhler's views were worthy of acceptance or not.

Blast Furnace Practice.—Fr. Schraml, of Pribram, discusses in "Stahl und Eisen," May 15 last, the heating of the charges in the upper part of a blast furnace. He calls attention chiefly to a point usually overlooked; viz.: that since the charges are warmed by the gases, the former must always be colder than the latter, and that the difference may be very considerable. At the throat, for instance, the gases are at 250° to 450° C., while the charges are nearly at outside temperature; below the throat, where the charges are, say, at 600°, the gases must be at some 450° higher temperature than at the throat, in order to be able to warm the charges to 600°, resulting in a gas temperature at that point of 750° C. From these calculations, the author draws the moral that the gases issuing from the blast furnace should be cooled down by being brought into proper contact with cold charge until their temperature is 100°, so as to utilize better their sensible heat in the furnace; but omits to point out the best way of accomplishing this end, which is to use hotter blast and dried blast, so as to run the furnace with less air blown in per ton of product, thus reducing the amount of gas passing upwards per unit of charge, and thus most effectively lowering its temperature.

Reduction of Ores.—Oskar Simmersbach, of Dusseldorf, makes some proposals in "Stahl und Eisen" of Oct. 15, which are more interesting than practical. He calls attention to the fact that iron ore is used on a large scale in open-hearth furnaces in connection with pig iron, and that, although only about three-quarters of the iron of the ore used is reduced to the metallic state, yet the iron as ore costs only two-thirds as much as iron in pig iron, and there is, therefore, pecuniary advantage in using as much ore as possible. The reduction of the ore to metal is performed by the action of silicon, phosphorus, manganese and carbon in the pig iron used, and the more highly oxidized the ore used (FeO, Fe^3O^4, Fe^2O^3) the less iron is reduced into the bath. The gist of Simmersbach's proposal is to previously partly, or nearly entirely, reduce the ore used to the metallic state, at least, let us say, to partly deoxidize it, so that when subsequently added to the pig iron bath in the steel furnace a much greater amount of iron is reduced into the bath. The reduction is to be done in a cylinder, in which the ore is first heated by burning blast-furnace gas in contact with it, and then deoxidized by passing blast-furnace gas alone through the heated ore, which is afterwards cooled out of contact with the air, and then used in the open-hearth furnace. The operation proposed would require much gas and entail extra labor charges, so as to probably eat up all the margin between cost of iron in iron ore and in pig iron. A more practical method of accomplishing the same end might be to impregnate a porous form of ore with carbon, such as coal dust, or to briquette it with coal dust, or impregnate it with waste tar or pitch, and in that form introduce it into the pig iron bath. The hot carbon would then certainly absorb some oxygen from the ore, and so increase the amount of iron reduced into the bath.

MISCELLANEOUS.

Gas Power.—As was noticed in this journal, Vol. III., p. 152, the New York Section of the Society of Chemical Industry devoted one evening last year to a discussion of

gas as a source of power. The complete report of this very interesting and successful discussion is now available in Vol. XXIV. of the "Journal" of the Society of Chemical Industry, No. 11. It contains the following papers: Willard L. Case, on generation of producer, Mond and blast furnace gas; Oskar Nagel, on the utilization of gas from suction producers; C. G. Atwater, on coke-oven gas; J. D. Pennock, on the Mond producer, with some shorter remarks by F. Schniewind, Franz Meyer and E. A. Uehling. This set of papers contains a very large amount of useful and reliable information, based on actual practice, and should be consulted by anyone interested in the subject from an industrial point of view. The theoretical side of the subject is presently discussed in J. W. Richards' Metallurgical Calculations, published in our columns.

Liquid Air.—At the recent meeting of the Association of German Naturalists, Pictet presented a paper in which he mainly attacked the theory on which Linde's method of liquefying air is assumed to be based. An abstract of the paper is given in "Zeit. f. Elektrochemie," Nov. 3. "Liquid air may find a useful application in practice, since nitrogen first evaporates from it and oxygen follows later. It is possible to obtain oxygen of any desired purity from liquid air. A 50 per cent oxygen, the so-called industrial oxygen, may find useful applications in many industries."

Cleaning Blast Furnace Gases.—Krull describes in "Glueckauf," of Oct. 28, the new cleaning and cooling apparatus for blast furnace gases devised by Bian and exhibited at Liége. The gas is purified so as to contain about 0.5 gram of dust per cubic meter, and the temperature is reduced to about 40° C.

Refractory Materials.

Magnesite.—E. Daumann, in a recent number of the appendix to "Jernkontoret's Annaler," describes the new magnesite industry of Norway. At the end of 1904 the "Norska Magnesit-Akteebolaget," with a capital of $50,000, commenced to exploit the deposits near to Snarum in Southern Norway. These deposits cover considerable ground, at a thickness of 4 meters. Works, with a yearly output of 2,500 tons of burned product have been erected, at which the rock is first crushed, then burned at a low, white heat; then ground, pressed into bricks under 200 tons pressure, and then burned at high white heat in regenerative furnaces. Analysis of a magnesia brick from this source shows 83.6 per cent magnesia, 4.6 ferric oxide, 2.0 alumina, 0.05 manganese monoxide, 9.3 silica, 0.046 phosphorus pentoxide, 0.003 sulphur, 0.50 loss on ignition. The bricks contain no lime, but are higher in alumina and silica than Styrian magnesia bricks. Dr. Bischof, of Weisbaden, testifies that the Norwegian bricks "are decidedly more refractory than the Styrian." It is interesting to know that increased supplies, of improved quality, of this very useful refractory are obtainable.

ANALYSIS OF CURRENT ELECTROCHEMICAL PATENTS.

Electric Furnaces.

Steel Mixer.—P. L. T. Héroult, 807,027, Dec. 12, 1905. Application filed April 19, 1905.

The inventor describes a mixer for steel of considerable capacity, to secure uniformity in the product of an entire works to secure a certain desulphuration and recarburation and conserve the oxidizable additions—such as silicon, manganese and the like—in order to reduce the quantities of these additions employed to a minimum. By reason of the metal being at a high temperature and in a very fluid condition, the oxides of silicon and manganese rise to the surface, leaving a clear product. Heat from the electric current has the advantage that it is non-oxidizing; moreover, the inventor maintains in the mixer a non-oxidizing atmosphere by the introduction, for example, of producer gas. The slag is thereby maintained deoxidized so as to favor the desulphuration of the metal. The mixer is closed. The aperture through which the electrodes pass is preferably made tight by a water-cooled pressure-gasket. The atmosphere within the furnace is maintained under pressure by the gas introduced from the producer.

"The largest charge ever smelted in an electric furnace, as far as I am aware, has been about 4½ tons. It is proposed to make this mixer large enough to carry a charge of 300 or 400 tons, to be fed by five or six Bessemer or Siemens-Martin furnaces." It is, therefore, of greatest importance to make the radiation losses as small as possible by providing a minimum surface. With a pig-iron mixer the temperature of liquefaction is about 1,050° C., and it is only necessary to pour in fresh iron from the blast furnace at sufficient intervals in order to maintain the mass in a liquid steel. With steel the temperature of liquefaction is 1,600° to 1,800° C., and it is necessary to apply additional heat.

An apparatus, "having a capacity of 100 tons, will require in order to maintain its temperature at that of the fusion of steel about 1,500 hp. If 2,500 hp. is furnished to the apparatus, there will remain 1,000 hp., producing 635 calories per horse-power per hour, which places at the disposal of the bath of steel 635,000 calories per hour. The specific heat of steel being 0.25, said quantity of heat is capable of reheating through 100° for an hour about 25 tons of steel, which are supposed to have been furnished to the mixer at a temperature already sufficient, or nearly sufficient, for tapping."

A 100-ton furnace, capable of reheating through 100° 25 tons for an hour, or of reheating through 50° 50 tons for an hour fed by a 2,500-hp. generator, should preferably have about the following dimensions: Surface of the bath, 26 square meters; depth, 1 meter. The electrodes, using a single-phase current, may be about 95 centimeters square in cross-section by 5 meters high, so as to assure their lasting six or seven weeks. With a three-phase current, using three electrodes, the cross-section should be proportionally reduced.

Referring to Fig. 1, a crucible a is closed by a cover b, through which pass three electrodes $c^1c^2c^3$. Each of these electrodes is carried by an arm, such as d^1 (or d^2 or d^3), of which the support e^1 is in engagement with, and may be raised or lowered by means of a system of pinions and an endless worm controlled by an electric motor f. Each vertical support e^1 is guided by rolls g between U-shaped members fixed upon the head of the crucible with interposed insulating material. Each carbon or electrode is embraced by a collar of metal sheets which is compressed or slackened by means of a screw h, operated by a wheel i through a suitable intermediate system of gearing. The crucible a carries a spout j, through which the metal may be poured out when the furnace is inclined. There are three doors $k^1k^2k^3$, corresponding, respectively, in position with the electrodes. The slag is ordinarily poured out of the rear doors k^2 and k^3, and the metal out of the front door k^1. The electrodes are surrounded by cooled pres-

sure-gaskets l. The crucible a is also provided with a passage m in communication with a gas producer n, from which the gases are led into the crucible a, which in operation is entirely closed. The metal and slag ordinarily occupy the positions indicated in Fig. 1.

The crucible a carries curved tracks, which rest upon a suitable pedestal o, and has its other point of support on

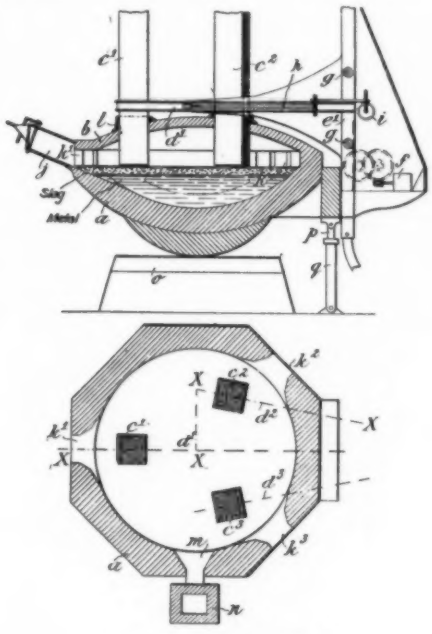


FIG. 1.—STEEL MIXER.

the articulated piston of a hydraulic cylinder q, which is also articulated and which serves to determine the angle at which the crucible is tipped.

Converting Cast Iron into Steel.—P. L. T. Héroult, 807,026, Dec. 12, 1905. Application filed May 19, 1903.

This is a combination patent for using an ordinary metallurgical steel process with subsequent refining in the electric furnace. Cast iron is first refined by oxidation, for instance, in the Bessemer converter, until the content of the molten metal in carbon has been reduced to between 0.02 and 0.05 per cent. When phosphoric pig is treated the oxidation is pushed further, until the phosphorus has been practically completely oxidized and has passed into the basic slag. The metal, instead of being further treated by addition of carburizing material, more or less rich in manganese, silicon, etc., in the converter itself, is then passed into the electric furnace, where it is kept in a state of fusion and is changed into steel of the composition wanted by the addition of carbon (in the form of "carburite") and of any desired ferro-alloys. The following table shows for a given percentage of carbon the minimum content of oxygen which may be obtained with the Bessemer converter and the electric furnace respectively (assuming an absence of manganese and silicon and the highest temperatures obtainable in the two apparatus:

	Bessemer.	Electric.
C = 0.05 or less.....	O = 0.75	O = 0.30
C = 0.10.....	O = 0.50	O = 0.01
C = 0.20.....	O = 0.30	O = 0.00
C = 1.60.....	O = 0.01	O = 0.00

In the Bessemer and open-hearth processes it is impossible to carry the oxidation sufficiently far to completely eliminate the impurities initially present, without leaving a considerable quantity of oxygen; but superoxidized metal, thus produced and formerly useless, can be satisfactorily treated in the electric furnace. The inventor gives the following table illustrating the percentage of imprities in good basic Bessemer steel and in a product of his own process:

	Bessemer.	Héroult.
Carbon	0.10	0.005 (to any desired maximum)
Silicon	0.01	0.000 (to any desired maximum)
Manganese	0.50	0.000 (to any desired maximum)
Phosphorus.....	0.07	0.005
Sulphur.....	0.07	0.005

Some of the eight claims seem very broad and of importance for the industrial development of the electrometallurgy of steel. The first claim reads: "A process for converting cast iron or the like into high grade or 'crucible' steel, which consists in first treating the metal in a Bessemer converter, then transferring it to an electric furnace, in which it is finally treated to deoxidize and carburize it." The third claim reads: "A process for converting cast iron or the like into high grade or 'crucible' steel, which consists in first refining it by oxidation and then removing the slag and transfering the remainder to an electric furnace, and there deoxidizing and transforming it into the desired product."

Resistance Furnace.—J. S. Dorian, 805,783, Nov. 28, 1905. Application filed March 27, 1905.

The construction is shown in Fig. 2. The carbon lining D of the furnace is connected with one pole of the electric supply, while the other pole is connected with the hollow graphite tube G; H being an insulating material. Inside of the graphite tube G, the resistor proper I is provided, which is brought to incandescence by the electric current. The temperature is regulated by raising or lowering the graphite tube G, so as to bring a greater or smaller portion of the resistor I to incandescence. If the exposed part of the resistor rod I burns off, or becomes broken, the same is replaced by sliding it downwardly in the graphite tube G, until it again makes contact with the bottom D, so that operation does not need to be discontinued.

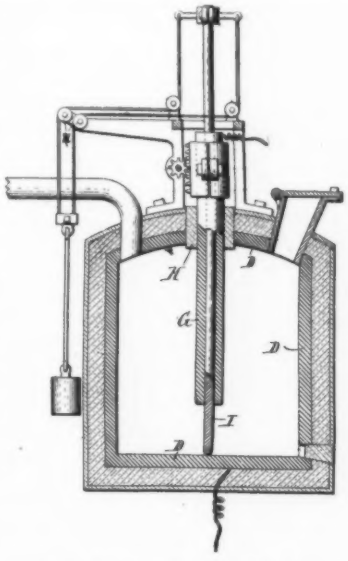


FIG. 2.—RESISTANCE FURNACE.

Resistance Furnace.—R. W. Meyers, 806,173, Dec. 5, 1905. Application filed Feb. 14, 1905.

The inventor uses resistors of refractory oxides, silicates, etc., which have a very high resistance at ordinary temperatures, but become conductors when heated. These he calls "pyro-electrolytes." They are formed into bars or rods and supported by graphite or metallic blocks. To start the furnace, the "pyro-electrolytic" rods are preheated by a blow-pipe, etc. To prevent too strong a current from passing through the furnace and destroying the graphite or metallic supports, the inventor prevents an outside shunt, the resistance of which increases with increasing temperature.

Metals and Alloys Free from Carbon.—F. von Kuegelen and G. O. Seward, 807,034, Dec. 12, 1905. Application filed Jan. 16, 1904. (Assigned to Willson Aluminium Co.)

In an electric furnace with carbon electrodes it is difficult to obtain chromium, ferrochrome, ferrotungsten, etc., free from carbon. The inventors cast the high-carbon metal or alloy, obtained in ordinary electric furnace practice, in form of pencils, and employ two such pencils in an electric refining furnace in which the carbon is eliminated by the decarburizing action of the slag or lining. A suitable slag for refining ferrochrome is a mixture of lime and chrome ore with suitable fluxes. Claim 1 reads: "Decarburizing a metalliferous substance by fusing it as an electrode in presence of a substance having a high affinity for carbon."

Electric Furnace for Bisulphide of Carbon.—E. R. Taylor, 805,501 and 805,502, Nov. 28, 1905. Application filed April 4, 1901, and June 2, 1902.

The inventor's continuous electric-furnace process for the manufacture of bisulphide of carbon has already been described and discussed on pages 60, 63 and 76 of our Vol. I. Patent 805,501 relates to the use of self-renewing electrodes adapted to perpetuate themselves in the continuously-working furnace and to feed themselves by gravity, as described and illustrated on page 76, Vol. I. Patent 805,502 refers to the treatment of the residue which would accumulate in the bottom of the furnace; the residue is fused by the electric current and is drawn off.

Electric Ring Furnace.—K. Meiser, 806,690, Dec. 5, 1905. Application filed April 26, 1904.

Several electric furnace chambers are arranged in a ring. Of the chambers but one is always in operation, while the other chambers are being cooled down or subjected to a preliminary heating by circulating air through the ring. The furnace is adapted for cases where close heating is required, as in the manufacture of incandescent-lamp filaments, and also for preheating materials which are non-conductors at ordinary temperature. Fig. 3 shows a plan view in the upper diagram and a section on line AB in the lower diagram. The electrodes p and n, which convey the current, are arranged at the top and bottom of each chamber, 1, 2, 3, etc. The bottom electrodes remain always in position, while a top electrode is introduced only into that compartment which is just at work; i. e., in the drawings into chamber 2. Chamber 2 is heated by electricity, chambers 8 and 1 are cooled down, chambers 3, 4, 5 are subjected to a preliminary heating, chamber 6 is recharged, and chamber 7 is emptied. The heat from chambers 8, 1, 2 is conveyed into chambers 3, 4, 5 by the circulating air, which enters into chamber 8, flows through chambers 1, 2, 3, 4, 5, and when slide a is open escapes from chamber 5 into conduit b. The furnace allows the air to be drawn off from the last chamber at as high a temperature as 500°, and even at higher temperatures, the entire heat which the air contains being passed into the first chamber without waste. The circulation is obtained through a ventilator provided at e, which when slide a is open draws off the air from chamber 5 into conduit b, and forces it from here into conduit f.

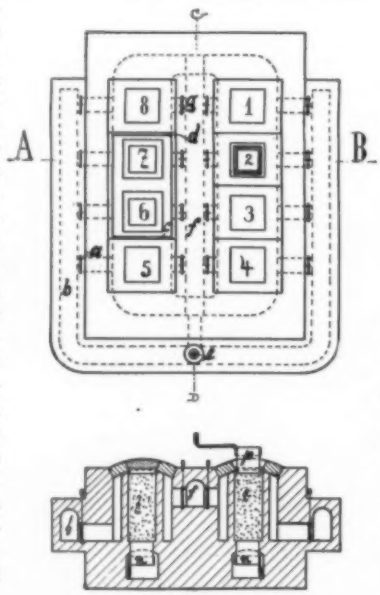


FIG. 3.—RING FURNACE.

Electrolytic Processes.

Separating Nickel and Copper by Electrolysis.—N. V. Hybinette, 805,969, Nov. 28, 1905. Application filed Nov. 25, 1904.

See the abstract under Recent Metallurgical Patents.

Production of Calcium.—O. Ruff and W. Plato, 806,006, Nov. 28, 1905. Application filed Jan. 20, 1903.

The inventors produce metallic calcium by electrolysis of fused calcium chloride with the addition of such calcium salts as are capable of lowering the melting point of calcium chloride. Suitable calcium salts of this kind are calcium sulphate, iodide, bromide and fluoride. The inventors preferably use the fluoride. Pure calcium chloride melts at about 780° C., while the melting point of a mixture of 1 kg. of calcium chloride and 165 grams fluoride is about 655° C. The density of the latter molten mixture is stated to be 2.5 (that of pure calcium at 29.2° C. is given by Goodwin as 1.5446). The melting point of metallic calcium is stated to be 780° C. The inventors carry out the electrolysis at about 760° C., with a cathodic current density of 3 to 6 amps. per sq. mm. The negative electrode is made of iron (the lower part of which may be heated to red heat, but below bright white heat); the positive electrode is made of carbon or nickel. The two electrodes are separated by means of a partition of suitable material, for instance, iron, which is immersed into the molten mass.

Bipolar Electrode for Electrolytic Production of Bleaching Liquors.—R. Kother, 806,413, Dec. 5, 1905. Application filed Sept. 7, 1905.

The electrode, shown in Fig. 4 in vertical and horizontal cross-section, consists of a thin layer a of platinum foil (of a thickness as low as one-two hundreths of a millimeter), covering one side of an insulating plate b of glass or india rubber. This side acts as anode. The platinum foil is folded just round the edges of the insulating plate, and makes thus contact with the graphite plate c which acts as cathode. The bipolar electrode is held together by the screws d. Instead of platinum foil a thin network of platinum may be used.

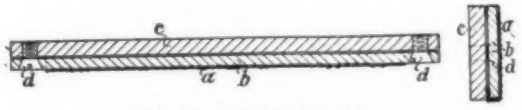


FIG. 4.—BIPOLAR ELECTRODE.

Electroplating Apparatus.—L. Potthoff, 806,835, Dec. 12, 1905. Application filed Dec. 1, 1904.

The inventor describes details of construction of a tumbling barrel for electroplating small articles in quantities. The barrel is made of skeleton construction, consisting of annular end pieces connected by longitudinal bars, on which is stretched on the inside a lining of heavy cocoa matting. This is sufficiently strong and durable to support the weight of the articles in the barrel and to withstand the abrasion due to the work and the rotation of the barrel; this lining is also sufficiently porous to permit the electrolyte to pass through, so that the anode may be disposed both within and without the barrel, thus securing a practically unlimited amount of anode surface. In one side of the barrel a longtiudinal opening is provided, and

interiorly over this is mounted a shield or hood, which, when the barrel rotates in one direction, prevents the articles to be plated from passing out, but which becomes effective when the barrel is rotated in the opposite direction, so as to discharge the articles out through the opening.

Purifying, Sterilizing and Ageing Liquors.—R. C. Turner, 12,421, Dec. 12, 1905. Application filed April 21, 1903, July 28, 1905.

The inventor provides a reservoir containing the liquid to be purified and a series of funnels and purifying vessels. The liquid passes from the reservoir into the first funnel, from there into the first purifying vessel, from which it flows over into the second funnel, then to the second purifying vessel and so on. All the funnels are connected to one pole of the supply circuit, while each of the purifying vessels contains an electrode at the bottom, all these electrodes being connected to the other pole of the supply circuit. When the liquid flows from one funnel on to the electrode plate on the bottom of the purifying vessel below, the electric circuit is closed through the liquid, and the liquid is treated by electrolysis, and is simultaneously acted upon by the oxygen of the air while it flows downwards.

ELECTRIC DISCHARGES.

Treating Solid Materials.—K. Birkeland and S. Eyde, 802,620, Oct. 24, 1905. Application filed Sept. 1, 1904.

Pulverized solid materials are treated by the effect of an electric arc, which is made to fill the interior of a furnace in a disc shape in the same manner as was described at length on page 399 of our Vol. II., in the same inventor's process of winning nitric acid from the air. The present patent refers to the reduction of ores, whereby the ores are in a powdered state and mixed with powdered coal. This mixture is passed downward through a vertical furnace chamber consisting of two walls 1 and 2 in Fig. 5, placed near each other. These two walls enclose a narrow but long and lofty furnace chamber. Through the end walls (not shown) the adjustable electrodes (7 being the cross-section of one of them) reach into the said chamber, so as to leave between their points a short adjustable space lying in a line connecting the magnet poles 8 and 9 of the vertically-arranged electromagnet 10, 11 and 12. The pole pieces 8 and 9 are provided with a number of radially arranged iron projections or arms 13, 14, for spreading the magnetic lines of force as far as possible out from the middle of the furnace. The electromagnet 10, 11, 12, is of large dimensions, but the electrical energy required by it may be small; for a 30 to 40-kw. furnace the energy of the magnetizing current is 0.4 kw.; 15 is a feeding device, by aid of which the pulverized material is fed into the furnace in a thin, even stream. It passes along or through the arc spread in the furnace for the whole extension of the same, and hereby will eventually be wholly or partly evaporized. The electrodes may eventually be made hollow and used for introducing gases—for instance, hydrogen, illuminating gas or other reduction gases. The solid particles having been treated, collect in the chamber 19, while 17 is the exit tube for the gases generated in the furnace.

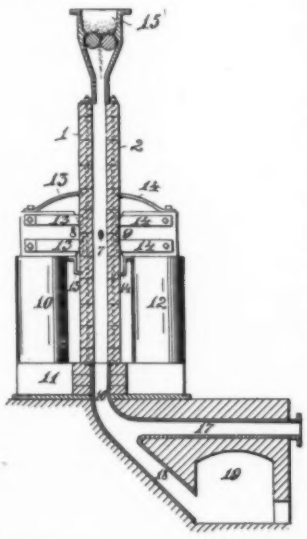


FIG. 5.—ARC DISCHARGE TREATMENT.

Production of Ozone.—A. C. Wood, 804,291, Nov. 14. Application filed Feb. 17.

Details of construction of an electrical apparatus for production of ozone by electrical discharges through oxygen. It consists essentially of a tubular conduit, an electrode composed of sheet metal bent along its length intermediate of its edges to provide a plurality of discharges, and insulating supports for holding the electrode in the circuit.

STORAGE BATTERIES.

To explain the absence of this division in our last and in our present issues, it should be stated that no storage battery patents have been issued during the last months, the last number of this department being No. 800,638, of Oct. 3, 1905, abstracted on page 433 of our Vol. III.

RECENT METALLURGICAL PATENTS.

NICKEL.

Separating Copper and Nickel.—Two patents have recently been granted to Mr. N. V. Hybinette, formerly with the Orford Copper Co., for the treatment of copper-nickel matte. The first patent (805,555, Nov. 28) relates to the treatment of "concentrated matte" (containing about 25 per cent sulphur and ½ to 5 per cent iron, the remainder being copper and nickel in differing proportions, generally 35 to 40 per cent of each metal) by the following three steps:

The first step is to grind and roast the matte. The roasted material is leached with sulphuric acid until the material will no longer neutralize the acid. Only dilute acid is used for leaching, so that the amount of free acid in the solution will at no time be more than 5 to 10 per cent. In this way it is possible to remove the bulk of the copper without dissolving much nickel; the solution will contain about one part of nickel to ten parts of copper. The solution so prepared is crystallized and boiled down, and again crystallized, and at each repeated crystalization crystals of commercially pure copper sulphate are obtained. The mother liquor contains copper and nickel in about equal parts; it is concentrated and boiled down to a solid mass of copper-nickel sulphates.

The material that has been leached contains about 55 to 60 per cent Ni and 12 to 18 per cent Cu, and is subjected to the second step of the process. It is mixed with sulphuric acid of about 60 per cent free acid, in such quantity that there will be sufficient acid to form sulphate of copper with all the copper present. The mass is then slowly brought up to a low red heat, and roasted at that temperature for a short time. Sulphates of copper and nickel are formed, but preferably the former. When the material reaches a temperature of about 800° C., the sulphates begin to decompose, but the nickel and copper sulphates are not affected in the same way. After completed decomposition, the material is drawn from the furnace and leached with weak sulphuric acid, whereby again a solution of about ten parts of Cu to one of Ni is obtained, which, upon crystallization, yields commercially pure copper sulphate. The mother liquor is boiled down, giving more salts of about equal parts of copper and nickel. This heating with sulphuric acid and leaching is repeated. The residue will then contain about 70 per cent Ni and 3 to 5 per cent Cu.

The third step is to mix this residue with hydrochloric acid or a mixture of common salt and sulphuric acid, and to heat again to a low red heat. The roasting operation is

continued until a maximum of copper and a maximum of nickel are present in form of chlorides. The material is then leached with water and weak acid, whereby a residue of practically pure nickel oxide is obtained with about ½ per cent copper still present. The nickel oxide is melted to metallic nickel anodes, which are electrolytically refined. This last leaching of chlorides leaves a solution from which no pure salts can be separated.

To sum up again, the first step yields copper sulphate crystals and a residue containing 55 to 60 per cent Ni and 12 to 18 per cent Cu. The second step treats this residue, and yields a residue containing 70 per cent Ni and 3 to 5 per cent Cu. This residue, when treated in the third step, yields metallic nickel.

The mother liquors, left in all three steps, and consisting of mixed copper and nickel salts in solution, are heated to a strong red heat, whereby all the nickel sulphate and chloride are changed into oxide. This residue is leached with water and weak sulphuric acid, whereby copper sulphate is again obtained and the residue of the leaching is nickel oxide.

The essential novel features are the second step and the combination of the three steps in one process. There are many electrolytic copper refineries which treat nickel-bearing copper. These plants make as a by-product a mixed sulphate of about equal portions of nickel and copper. This may be handled as the mother liquor from crystallization of copper.

Electrolytic Process for Separating Nickel and Copper.—The second patent of Mr. N. V. Hybinette (805,969, Nov. 28) refers to an interesting electrolytic process, the apparatus being shown in Fig. 1. A is the tank, C the cathode, and B the anodes. The cathode is surrounded by a porous diaphragm D, constructed of a wooden frame K and two thicknesses of cotton cloth D, at a distance of about ½ inch from each other. F is the inflow for the electrolyte, G the overflow; they are so adjusted that the level H of the electrolyte in the cathode compartment inside the porous bag is about 1 inch above the level I in the anode compartment. The electrolyte is thus caused to flow in a regular stream from the cathode to the anode, in a direction perpendicular to both plates. The cotton cloth D is very porous, and "the diaphragm bag is, in other words, only a convenient mechanical device for directing the circulation of the liquid in a direction from cathode to anode.

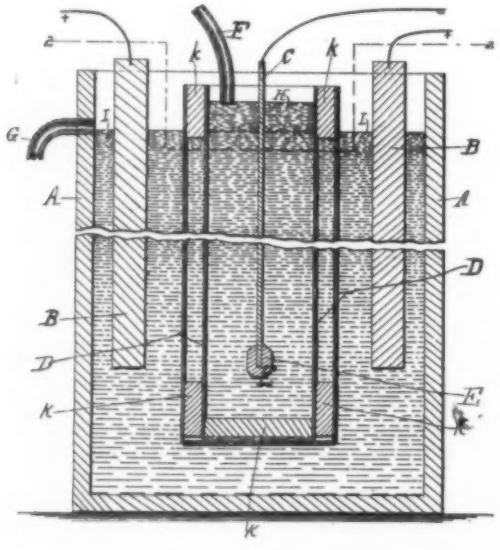


FIG. 1.—ELECTROLYTIC CELL FOR SEPARATING COPPER AND NICKEL.

The cathode starting sheet C is made of copper (greased so that the nickel deposit may be easily removed), and is prevented from warping by the wooden rip E. The anode plates are cast from the nickel-copper alloy which is to be separated; they should contain less than 1 per cent of sulphur and less than 3 or 4 per cent of iron. The electrolyte consists of a dilute solution of pure sulphate of nickel with a small proportion of a weak acid—such as phosphoric acid, boric acid, etc. During the operation nickel is deposited on the cathode, while an equivalent amount of both nickel and copper, with some iron, goes into the solution from the anode. Thus the solution in the anode compartment becomes gradually richer in copper and iron, but it is prevented from passing over into the cathode compartment by the flow of the liquid through the diaphragm in opposite direction. The solution in the cathode compartment is relied upon to remain pure nickel sulphate. After the porous bag has been in use for some time the pores become filled up with slimes of boric salts. Any platinum, palladium, gold, etc., contained in the anode, together with considerable copper, especially copper sulphide, pass into the anode slime. The anodic solution of mixed nickel and copper sulphates passes continuously off through G, and is regenerated outside of the cell as follows:

The copper is removed from the solution by cementation upon nickel or a nickel-copper alloy, which must be free from sulphur, silicon and carbon. Under these conditions the cementation is quick, if the solution is kept at a boiling temperature. The solution flowing off from G is, therefore, first passed through a tank, in which are suspended slabs of a nickel and copper alloy, containing, say, 30 per cent of copper, and then through a second tank containing pure nickel slabs. Any copper in the solution is thereby cemented out. To remove the iron, anodic oxidation (with insoluble anodes) and precipitation with nickel carbonate are employed. All the copper and iron are thus removed from the solution, while the nickel content is simultaneously raised again to its original value. The solution is now ready to be supplied again through F to the electrolytic cell. The electrolyte thus passes through a complete cyclic process.

Zinc.

Zinc and Lead from Complex Sulphide Ores.—A process of A. H. Imbert (807,271, Dec. 12) is based on the property of metallic copper to act as a very energetic desulphurizer toward most of the ordinary metals. In particular, if granulated copper be mixed with crushed zinc sulphide, or with galena in the proper proportions, the reactions will be with galena at 800° C.:

$$PbS + 2Cu = Cu_2S + Pb,$$

and with zinc blende at 1,100°:

$$ZnS + 2Cu = Cu_2S + Zn,$$

the zinc escaping from the molten mass under violent ebullition and being condensed outside. With a complex sulphide ore the same two reactions as above will take place successively, but at temperatures varying in accordance with the predominence of one sulphide or the other. If care be taken to protect the lead which accumulates at the bottom of the crucible from exposure to the greater temperature necessary for vaporizing the zinc, the contamination of the zinc vapors with those of the boiling lead is prevented. Two forms of apparatus are described. The copper sulphide is reduced again to copper by the Bessemer process, and the copper is used again with new zinc and lead sulphides.

Zinc Furnace.—E. Dor-Delattre (806,121, Dec. 5) patents details of construction of regenerative gas furnaces, to obtain a constant and regular temperature in every part, and

to prevent the fouling of the openings for the entrance of the air and gas. The principal feature is the arrangement of the openings for the entrance of the air and gas, so as to be easily accessible and adjustable. The burner gaps are provided with movable blocks or slabs, whereby the air and gas currents can be altered and regulated at the moment of entering the furnace. The openings which connect the two furnace chambers are so shaped that they compel the proper mixing of the air and the part of the gas which has not been burned in the first chamber, and to insure complete combustion of the whole of the gas.

Zinc, Gold, Silver from Ores.—J. Nicholas (805,577, Nov. 28) treats ores, matte, slimes, etc., containing zinc, cadmium, lead and precious metals as follows: The material is pulverized, mixed with water to a pasty condition and sodium chloride, and is then heated in an oven under exclusion of air, whereby the zinc and cadmium compounds are changed into chlorides. These are leached out, the cadmium is precipitated by sulphuretted hydrogen, and the zinc by milk of lime. The residue of the leached mass contains lead, silver and gold, is fluxed in a furnace, and the metal so obtained is remelted, and when in a molten condition aluminium is introduced into it and the whole kept in agitation until the aluminium melts and becomes alloyed with the gold and silver. On cooling, the aluminium separates from the lead and rises as a crust to the surface, carrying with it the gold and silver.

BOOK REVIEWS.

HIGH TEMPERATURE MEASUREMENTS. By H. Le Chatelier and O. Boudouard. Translated by G. K. Burgess. New York: John Wiley & Sons. Price $3.00.

The second edition of Dr. Burgess' translation of "High Temperature Measurements" is of especial interest to those engaged in electrometallurgical work, because of the additional work done since the appearance of the first edition of the book. In his preface to the second edition Dr. Burgess says: "The greatest advances have been made in optical pyrometry, and the chapter on this subject has been greatly extended and preceded by one on the laws of radiation."

In dealing with the highest temperatures, such as those used in the electric furnace, it is not possible to use thermo-electric or resistance pyrometers, the temperatures reached being altogether too high. Thus it is to the optical pyrometer that we must turn when it is desired to study electric furnace temperatures, and there can be no doubt that when the problems involved in the application of optical pyrometry are solved, great improvements in electric furnace practice will be effected.

It might be thought that a serious difficulty that will be experienced in the application of the optical pyrometer lies in the formation of vapors that will obstruct a view of the interior of the furnace. Suppose, for example, that a tube furnace is in use, and that the heating is obtained by passing a current through the tube, which is made of carbon. As the temperature rises the tube will rapidly become filled with dense vapors, probably due to the vaporization of impurities, such as silica and iron in the carbon, and these will certainly cut off a large amount of light. Even if the carbon composing the tube is pure, vapors will be obtained from the surrounding material, whatever that may be, since carbon becomes very porous to vapors when at a high temperature. It would be interesting to get a reply to this objection from optical pyrometer experts.

As a concise statement of what has already been accomplished in the methods of measuring high temperatures, the book will be found useful by all metallurgical engineers who wish to get an exact record of the course of temperature during all stages of operation.

MONOGRAPHIEN ÜBER ANGEWANDTE CHEMIE. Vols. XI. to XVII. Halle a. S.: W. Knapp.

During the past year our German cousins have been indefatigably turning out the monographs on applied electrochemistry, from the press of Wilhelm Knapp in Halle.

Among the works which have recently appeared we note the following:

(Vol. XI.). DIE GALVANOPLASTIK. By Dr. W. Pfanhauser. 130 pages. Price 4 marks.

This is a very practical and timely work, written by a technician well posted on the subject. He gives extensive details of the forming of the moulds, making them conducting, composition of the depositing baths, handling of anodes and production of various specialties, such as cliches, grammophone plates, engravings, etc. It is a skillful presentation of the subject brought up to date.

(Vol. XII.). DIE ELEKTROCHEMISCHE INDUSTRIE DEUTSCHLANDS. By P. Ferchland. 64 pages. Price 2.50 marks.

In the narrow limits of sixty-four pages one could hardly expect a very thorough presentation of this subject, but, nevertheless, one is entitled to expect more than the author has gotten into them. The treatment of the subject is unsatisfactory, and the monograph a disappointment.

(Vol. XIII.). CARBORUNDUM. By F. A. J. FitzGerald. 44 pages. Price 2 marks.

The author has been intimately connected with the carborundum industry, and his work is eminently satisfactory, not only from the standpoint of the description of the details of manufacture of this distinctively electrochemical product, but also satisfactory from the standpoint of general information concerning the erection and running of large incandescent electric furnaces.

(Vol. XIV.). ELEKTROLYTISCHES VERFAHREN FÜR HERSTELLUNG PARABOLISCHER SPIEGEL. By Sherard Cowper-Coles. 30 pages. Price 1 mark.

A short paper, which should have appeared as a contribution to some journal or scientific society. The author describes only his own process, and undoubtedly the publication of this fragment as one of the "Monographs" has lowered the dignity of the series.

(Vol. XV.). ARTIFICIAL GRAPHITE. By F. A. J. FitzGerald. 60 pages. Price 3 marks.

This is one of the strongest monographs of the series, in that it describes in detail, and at first hand, the actual manufacture and properties of this interesting product. Some foreign scientists contest very vigorously the theory of its production, as explained by Mr. Acheson, the inventor, and described in detail by Mr. FitzGerald, but a few years will settle that dispute, leaving untouched the practical details so closely and minutely described.

(Vol. XVI.). DIE DARSTELLUNG DES ZINKS AUF ELEKTROLYTISCHEM WEGE. By Dr.-Ing. Emil Günther. 240 pages. Price 10 marks.

This work is a welcome contribution to electrometallurgy. The author was a student under Dr. Borchers, and had the benefit of the advice of this redoubtable electrometallurgist, as well as of living in a part of Germany where the electrometallurgy of zinc first took root. The processes are very systematically grouped into the treatment of aqueous solutions and of fused salts, and the former systematically sub-divided. It is to be regretted, however, that the author did not include the electric furnace processes within the scope of his treatise.

(Vol. XVII.). HYPOCHLORITE UND ELEKTRISCHE BLEICHE. Theoretical part. By Dr. Emil Abel. 110 pages. Price 4.50 marks.

While this monograph is a very interesting and readable one, and contains some information concerning *why* and

wherefore which will be of value to practical electrochemists (together with a great deal of theoretical speculation which will never be of use to anyone), yet its appearance in this series of monographs on "*Applied* Electrochemistry" is an anomaly, and gives the impression of padding the series. Our advice would be to the publishers to put such works as this into a new series of monographs on "Theoretical Electrochemistry."

California Water-Power Plant.

Our most up-to-date metallurgical plants are now covered with networks of electrical circuits, supplying electrical energy for lighting, traction, and especially for all possible power purposes. This is in accordance with the prevailing tendency in our industries of pushing the output of a plant to the maximum limit by substituting machines and automatic devices for human labor, wherever possible; and there is no energy form so flexible and transportable as electrical energy. Naturally, electric power is now also seriously entering the mining field, but while the progress is steady, yet it is relatively slow. The principal problem is here the power problem: how to generate the electrical energy in the cheapest way.

This problem has repeatedly been discussed in these columns, and it has been pointed out that there is not one and the same solution of the problem in all locations. According to the local conditions, water power, gas power, or steam power may be preferable. For mining purposes, water powers are often available and easy to develop. In this respect a new water-power plant at the Pacific Coast—that of the North Mountain Power Co.—contains much that is of interest. This plant has really been erected rather with an eye to the future than for the present need of the communities which it serves.

This plant is located in the central part of Trinity County, California, 2 miles below the town of Junction City, where Canon Creek, from which the water used for power is obtained, flows into the Trinity River.

Weaverville, the county seat, is 12 miles distant by road. The nearest railroad point is Redding, on the "Shasta Route" of the Southern Pacific Railroad; Humboldt Bay, on the Pacific Ocean, with Eureka, the chief coast city of Northern California, lies almost due west, distant 59 miles in a straight line.

The altitude of the plant is about 1,400 feet. All material, cement and machinery were hauled in over 60 miles of the severest mountain roads, across three distinct divides or summits, viz.: Trinity Mt., Brown's Mt., and Oregon Mt. It required eighteen to twenty animals to pull each of the larger pieces, weighing 18,000 pounds up the grades, and when mud was encountered it was necessary to hitch eighteen animals to the fall of a block and tackle fitted with steel cables. Despite these difficulties, however, no mishap occurred to any of the machinery.

Watershed.

The water used at the plant is diverted from Canon Creek, which has a drainage area of 52 square miles above the diverting dam. The upper part of the basin is a rugged, glaciated granite country, extending up to an altitude of from 9,000 to 10,000 feet above sea level, where some snow remains throughout the year. The higher parts of this basin are in the nature of an immense ampitheater, lying on a flank of Thompson Peak, which is a characteristic feature of all elevated glaciated topography. And, as is so often the case, the converging and descending glaciers have scooped out immense holes with almost perpendicular sides, which now form the beds of two lakes. These have been utilized as storage reservoirs.

Ditch System.

The dam is small, and serves merely for diverting the water. It is of the usual rock-filled crib form, which has been the type used for many years in mining operations on the Pacific Coast.

The ditch system consists of alternating sections of ditch, flumes, and one tunnel. Part of the ditch is cut in solid rock,

FIG. 1.—18-HORSE TEAM HAULING THE LOWER HALF OF STATOR OF A 750-KW. ALTERNATOR OVER 60 MILES OF MOUNTAIN ROAD.

but the most of it is dug in the side-hill soil which stands well and puddles well.

The flumes are nineteen in number, and vary in length from 30 to 1,200 feet. Those immediately below the dam are laid upon a solid bed-rock bench, and equipped with adequate spillways, waste-gates and sand-boxes. The total length of the flumes is 5,250 feet.

A tunnel 1,821 feet long has been driven to replace a temporary flume which was unavoidably built upon treacherous sliding ground. This tunnel is heavily timbered throughout its entire length, and tightly lagged except where the rock is unsusally hard. The dimensions of the main tunnel are 4 feet 9 inches by 5 feet 10 inches in the clear. The total length of the ditch, flumes and tunnel is 7¼ miles.

The average grade of all is 0.00184 or 9.73 feet per mile.

The Penstocks.

The penstocks, two in number, are each 1,165 feet long. Under a total head of 604 feet there is an effective head of 600 feet, or working pressure of 260 pounds per square inch.

There is one complete independent penstock for each of the two units.

Buildings.

The plant proper consists of (1) the power house, (2) the transformer house, and (3) the high-tension switch house. In addition there are (4) the shop, (5) the operator's dwelling, and (6) the stable. At the forebay is the forebay tender's cabin, and at the dam is a house for the tender of the head gates.

FIG. 2.—TRINITY RIVER PLANT OF NORTH MOUNTAIN POWER CO.

Power House.

Each of the two hydraulic units consists of a pair of 44-inch Pelton wheels under one sheet steel housing, provided with ring-oiling, self-aligning bearings, coupled to the generator

through flexible leather link couplings. The nozzles are of the deflecting type. With the largest tips in service the wheels are capable of driving the generators at 25 per cent overload.

The wheels are controlled by type "F" Lombard governors using oil. The pressure and vacuum are maintained by oil pumps belt-driven from the wheel shafts.

The governors are not fitted with any form of switchboard speed control, but a single operator has no difficulty in synchronizing a generator under the load conditions which exist in the plant.

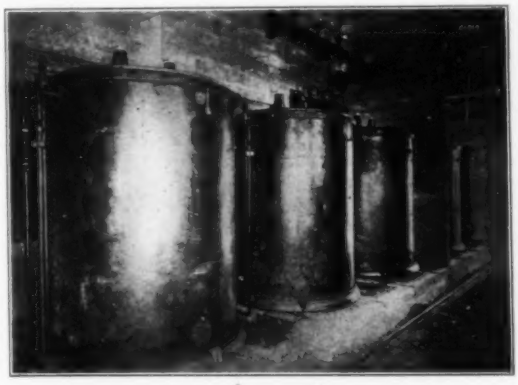


FIG. 3.—OIL-FILLED, WATER-COOLED, 300-K. V. A. TRANSFORMERS IN TRANSFORMER HOUSE.

The tail-race is 6½ feet wide, and excavated for 280 feet through bed rock to the Trinity River.

The generators, two in number, are of the Bullock type, furnished by Allis-Chalmers Co., of Milwaukee, being three-phase, 750 kw., 500 r. p. m., 2,200 volts, 25 cycles, rev. field, 6-pole.

Two Bullock exciters 125 volts, 45 kw., 900 r. p. m., are driven by belts from the generators. The switchboards are of marble and have Wagner instruments.

TRANSFORMER HOUSE.

The transformer house, like the power house, is built of concrete. It contains seven step-up transformers, viz.: two banks of three each, and one in reserve. They are of Bullock make, 300 kilovolt-amperes, water-cooled, oil-insulated, 2200/19050 volts, 25-cycle. Each bank is located in a separate room, and the seventh, or spare transformer is in a third room. They stand upon rollers, which in turn rest upon T-rails set into concrete piers. The spaces between the piers are filled with gravel and provided with sub-drainage so as to allow any oil to rapidly escape in case of leakage or accident. The water piping is connected up with unions, and so arranged that every transformer is interchangeable with every other one, as far as water and electric connections are concerned.

A track runs the entire length of the building, and at such an elevation that the floor of a car is at the same height as the rails, which are imbedded in the concrete piers. Thus any transformer can be quickly rolled out upon the car, removed, and another reconnected in its place in case of accident.

The penstocks are each tapped in the power and after passing through shut-off and throttling valves under the control of the operator, water is delivered into a cylindrical steel tank, set upon a little knoll about 20 feet above the level of the transformers. From this tank the water circulates through the cooling coils of the transformers by gravity.

The transformers are connected in delta on the low-voltage side, and in Y on the high-voltage side, with ungrounded neutral.

THE HIGH-TENSION SWITCH HOUSE.

In the high-tension switch house are two banks of "M-T" single-throw air-brake switches, and G. E. alternating-current multiplex lightning arresters, connected up for the three-phase circuit.

POLE LINE.

The pole line extends almost due west from the plant to the sub-station in Eureka. The length is 65 miles. Of this, 55 miles are over a severely rugged mountainous country; the altitude of the plant is only 1,480 feet, and Eureka is at sea-level, but the line passes over several summits ranging from 4,500 to 5,500 feet in altitude. Fifty miles of its length lie in a heavily timbered country, requiring a tremendous amount of clearing, the trees ranging from 2 feet to 4 feet in diameter. It was necessary to construct a trail nearly the entire length of the line.

The route deviates from a straight line only slightly and only where the topography made it unavoidable.

It is a "thorough" transmission, so to speak, there being no taps on the line anywhere between the plant and the sub-station at Eureka.

The line is a single circuit, three-phase, averaging thirty-five poles to the mile.

The poles are redwood at the western end; in the inaccessible stretches the native red fir was the only wood available.

Insulators are Locke two-piece single petticoat porcelain, 8½ inches in diameter. In the fog-belt a larger insulator of similar design is used.

Pins are sun-dried eucaluptus, oiled, 1½ in diameter.

The spread of wires on the standard length spans is 40 inches; wire is No. 4 copper, except on some long spans where stranded cable is used.

The length of spans varies from 50 to 1,400 feet, according to the conditions and topography of the country.

The potential at present used on line is 30,000 volts.

SUB-STATION AT EUREKA.

The sub-station at Eureka includes an auxiliary steam plant as follows:

Two (2) B. & W. water-tube boilers fitted with Peabody patent oil-burning furnaces duplicate-oil pumping system;

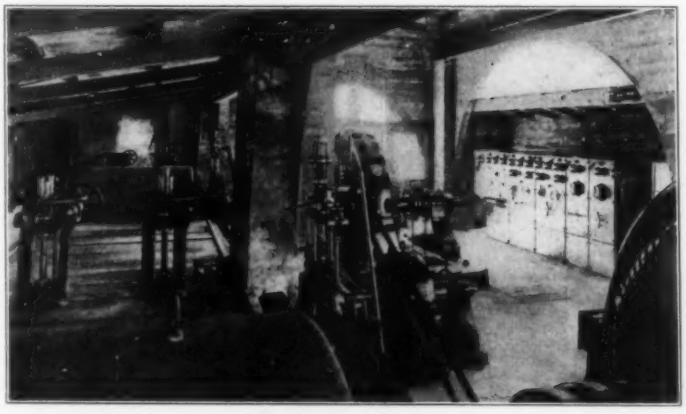


FIG. 4.—VIEW IN POWER HOUSE, SHOWING WATER-WHEEL HOUSINGS, GENERATOR AND SWITCHBOARD.

Goubert auxiliary feed-water heater; Wheeler "Admirality" surface condenser with self-contained steam-driven air and circulating pumps, cooling water being taken from Humboldt Bay, and a McIntosh & Seymour tandem compound engine of nominal rating of 700 indicated horse-power. A jackshaft running at 500 r. p. m. is connected to engine by rope-drive.

A Bullock rotary converter, 500 kw., 500 r. p. m., 6-pole, 25-cycle, 550-volt, is arranged for direct connection to this jackshaft by a jaw clutch and so driven by the engine. This permits of carrying the load by steam when necessary to shut down the transmission line for repairs.

The engine is fitted with a switchboard speed-control device.

The clutch has a synchronism indicator in the nature of a lamp, so that the engine may be connected to the rotary while it is running at full speed on the power transmitted from the Trinity River plant.

For the rotary converter there are three Bullock transformers, 190 kw., water-cooled, 25-cycle, 30,000/352 volts. For stepping down for the local distributing system are three G. E. transformers, 400 kw., water-cooled.

For furnishing power to the 60-cycle incandescent and arc

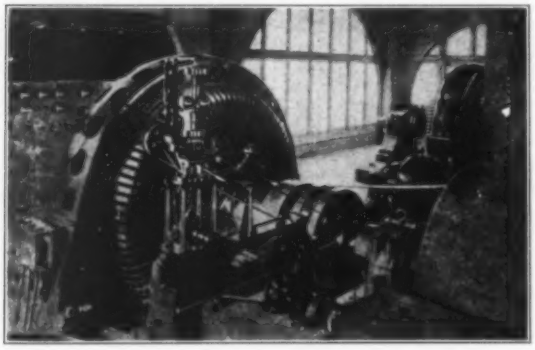


FIG. 5.—750-KW. ALTERNATOR AND WATER-WHEEL GOVERNOR.

lighting circuits of the city of Eureka, a three-phase, 60-cycle generator is driven by the rotary, acting as a synchronous motor.

The sub-station is fitted with switch boards and h. t. switches suitable for handling this equipment.

A fuel-oil tank 54 feet in diameter by 25 feet deep, holding 10,000 barrels, has been built near the substation, and is connected to a dock on Humboldt Bay by a pipe line.

The load at present consists chiefly of lights in the city of Eureka. Some motors are already connected to the circuits, and the motor load is being rapidly developed.

Vaporization of Jacket Water.

The amount of water needed for cooling water jackets in the usual way is quite considerable, and in places such as Leadville, Denver and other towns, where some of the smelting companies buy the cooling water from the city water companies, the expense for this apparently small item is very high. In such cases a considerable saving may be accomplished by the system of vaporization of jacket water, patented by the Colorado Iron Works Co. This system is discussed at length in the book recently issued by this company, entitled "Some Details as to Smelting Practice and Equipments."

The method is based on the well-known fact that water boiling at 212° F., when changed into steam of the same temperature, absorbs a certain amount of heat from the surroundings. This heat represents the energy required for the change from the liquid to the gaseous state, and because it disappears with the formation of the steam it is spoken of as the latent heat of steam. The change of 1 pound of water at 212° F. to steam at the same temperature absorbs 966 B. T. U.

If the jacket water is simply heated to a higher temperature and discharged as water, the heat absorbed is simply the so-called specific heat. If it is discharged as steam, the heat absorbed is the sum of specific heat and latent heat. Let us assume that the water is supplied to the jackets at 62° and discharged as water at, or just below the boiling point, 212°, then the water is raised in temperature 150° F., and since 1 pound of water needs 1 B. T. U. to be raised by 1° F., every pound of cooling water absorbs under those circumstances 150 B. T. U. If the water is not discharged as liquid water of 212°, but as steam of the same temperature, each pound absorbs not only those 150 B. T. U. but 966 additional heat units (latent heat), that is, in the whole, 1,116 B. T. U. In other words, the heat absorbed, or the cooling effect, is in the latter case seven and one-half times greater if steam is discharged instead of water. Or to produce a certain cooling effect, seven and one-half times less water is required. Of every 7½ pounds of water used when water is discharged, 6½ pounds thus appear to be wasted. This explains why, under a great many conditions of practice, a very considerable saving may be accomplished by means of vaporization of jacket water.

Some slight change from the usual forms has to be made in the necks and backs of the jackets, as rounding corners and enlarging outlets, to avoid spasmodic ebullition and adapt them to the conditions involved.

Steam may be discharged directly from the several water-jacket sections, but a better method is to connect all the sections by means of pipes to a horizontal drum on each side of the furnace. The jackets and pipes are kept full of water. The level is maintained somewhere near the centers of the drums, and the separation of steam takes place in the drums and escape pipe leading the steam away to the open.

The vaporizing system prevents deposit of lime and other impurities on the inside of the jackets to some extent, though not wholly. There is by far less water used in this system, and to that extent there is less deposit of sediment in the jackets. Water is not vaporized from the jackets but from the drums or tanks to which the jackets are connected. Hot water in the jackets rises to the top and thence up through the dis-

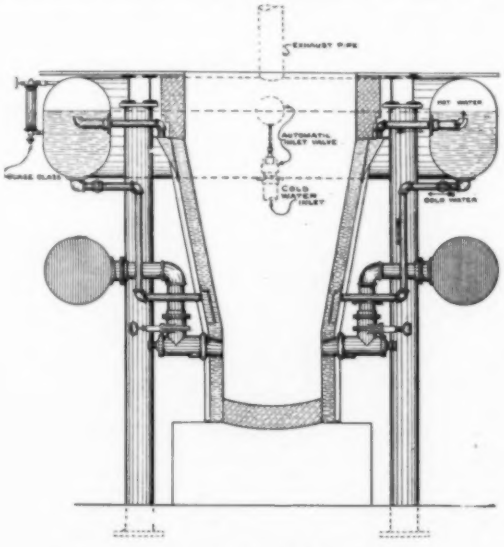


FIG. 1.—VAPORIZATION OF JACKET-WATER.

charge pipes to the surface of the hot water in the drum, where it bursts into steam. Hot water cannot go to steam below when the way is open for it to rise, but steams at the surface. As all the steaming is done at the surface of the water in the drums so all, or most, of the combined impurities in the water are deposited in the drums, which are very easily cleaned out and cannot be damaged by such deposits.

This system is perfectly adapted to vaporizing, as also to overflowing jacket water, no change whatever being necessary other than to open a valve in the apparatus when changing over from the one to the other. As the water supply runs

short if overflowing, vaporization at once begins automatically and continues to compensate for whatever shortage there may be in overflow supply until the supply dwindles away down to one-eighth the ordinary supply necessary for overflow when discharging boiling water, and at that point all is evaporated and the supply must not run lower. There is no disadvantage whatever in evaporating the whole necessary, while there is much advantage in the system, as pointed out above.

It is sometimes the practice among smelter people to run so much water through the jackets that it is discharged at a temperature much below boiling. This is done under the impression that the jackets are more durable when kept at the lower temperature. This, however, is a misapprehension, for as a matter of fact cast iron as well as wrought iron has greater strength and a greater elastic limit at 400° F. than it has below that temperature. The heat of jackets will not be variable when vaporizing, or in any case where this system is used, as it is by the common method of discharging water when the supply turned on them is varied.

There are more cast-iron jackets broken and more plate-steel jackets damaged by running an excess of cold water

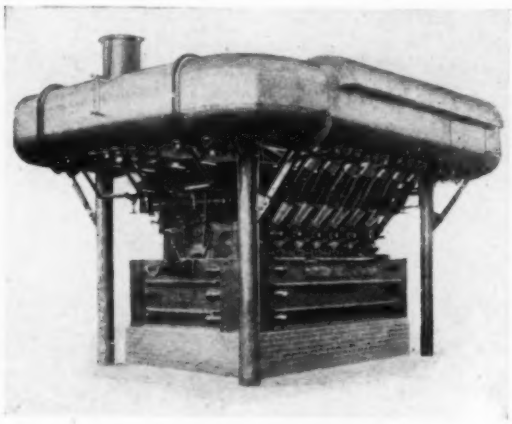


FIG. 2.—LEAD FURNACE WITH VAPORIZER EQUIPMENT.

through them than in any other way. The hotter jackets can be kept up to 400° F. the more durable they will be.

The construction is shown in Fig. 1. Water enters the vaporizer at the bottom of the back end section of the tank, through the automatic inlet valve, which admits only just enough water to take the place of that passing off as steam. Its action is constant, it has no wearing parts, and hence is everlasting.

In Fig. 1 this end section of the tank, with the inlet valve and its chamber and float and the exhaust pipe, are shown in dotted lines, all being at the opposite end of the furnace from the observer and seen through, as it were.

There is no possible contingency to prevent its working, and it always works just as long as the float floats, and it carries the valve with it, admitting more or less water to maintain the level constant, in the tank.

No water overflows from the tank or drum, or is lost in any way, except just what is vaporized and passes off through the exhaust pipe as steam.

From the bottom of the tank water passes down through pipes into each jacket respectively.

Two of these pipe connections, one on each side of the furnace, are shown in the cut, extending from the bottom of the tank downward and into the jackets above the tuyeres. Each jacket has its independent down-pipes from the bottom of the tank, in like manner as those shown.

The water entering the bottom of the tank cold, so remains cold at the bottom, only rising as that at the surface vaporizes off and is continuously supplemented from below with cold water. The cold water entering the jackets by the supply pipes becomes heated in the jackets and rises to the top and thence out, discharging from the tops of the jackets through suitable pipes at the surface of the water in the tank, where it bursts into steam and so passes out to the atmosphere through the exhaust pipe.

Fig. 2 shows a lead furnace equipped with this vaporizer appliance.

Portable Moving-Coil Galvanometer.

Patents have recently been granted to the Leeds & Northrup Co., of Philadelphia, for a portable moving-coil galvanometer. The distinguishing novel feature is the method of suspending and winding the moving system.

The suspension consists of upper and lower filaments, and in this particular it differs from the pivot and jewel as ordinarily used in instruments of the portable type. These filaments are fully protected against breakage in a manner to be described later. This arrangement of the filament suspension permits high sensibility and avoids the initial friction to be overcome when jewel bearings are adopted as a means of suspension. This is of importance, especially when the galvanometer is used for zero methods, and by reason of this fact it can be substituted for instruments of the mirror type in potentiometer work for accuracies of 1-5 per cent and in all Wheatstone and slide-wire bridge measurements to commercial accuracies. Its high sensibility makes it available for use in many cases where it was ordinarily supposed that it is necessary to use a non-portable suspended coil galvanometer. The entire construction of the instrument is one of extreme simplicity and compactness, while at the same time preserving the sensitiveness and general efficiency of other forms which it has hitherto been considered impracticable to make so simple and compact.

The magnetic field is produced by a U-shaped cast-iron permanent magnet, Figs. 2 and 3, having inwardly directed poles at one end, so as to have north polarity only on one side of the air gap, separating the poles, and south polarity only on the other side of the air gap. The magnet is slotted so as to accommodate the moving system as shown. The air gap between the poles being very short the field is uniform and intense.

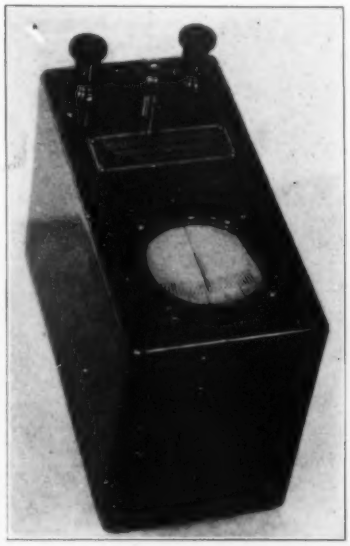


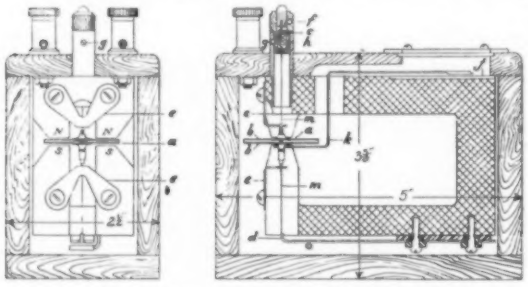
FIG. 1.—PORTABLE GALVANOMETER.

The moving system consists of four flat coils of very fine wire wound alternately in opposite directions, so as to produce alternate north and south poles when viewed from one side, as shown in diagram in Fig. 4.

These coils are held between two aluminium discs b, and suspended in such a manner that normally only a portion of each coil extends into the air gap between the magnet poles, though at all times only about one-half of the coil surface is between the pole faces. It is evident, therefore, that when current is passed through the coils (see Fig. 4) two of the coils of like polarity will then

swing around to inclose the greatest number of lines of force, while the other two coils of like polarity will be repelled. The aluminium discs b also serve the purpose of damping the system and rendering it dead-beat. The galvanometer can be given a high, medium or low resistance by connecting the coils in series, series-parallel or parallel.

The suspensions consist of three wire filaments of a high



FIGS. 2 AND 3.—DIAGRAMS OF CONSTRUCTION.

tensile strength, which are non-corrosive. To give the entire system resiliency in the event of sudden jars, the upper suspension terminates in a spiral spring c, and the lower suspension is attached to a long, flat phosphor-bronze spring d, as shown in Fig. 3. An additional protection against excessive strains on the moving system is provided by means of two guards e. These guards have clearance holes to provide for the rotation of the system around its axis of suspension, but to limit the sidewise movement or play of the system, thereby arresting the movement of the coil due to any sudden shock. The movement of the system vertically is limited by the pole faces of the magnet, which also prevents breaking of the wire filaments.

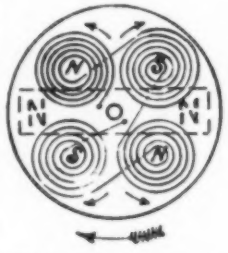


FIG. 4.—MOVING SYSTEM.

The torsion head f provides a delicate zero adjustment, and by means of the screw g, operating in an annular groove h, engages the end of the groove and thus acts as a stop to limit the extent to which the torsion head may be turned, and therefore prevents the suspension filament from being twisted off by turning the adjusting head too far.

The magnet with its complete moving system and scale is mounted in a highly polished mahogany case, as shown in Fig. 1. A circular opening in the top, protected by a glass window, provides for the visibility of the scale. The binding posts are securely mounted as indicated, and are arranged to clamp large or small wires. The outside dimensions of the case are 5 inches x 2½ inches x 3½ inches high.

Industrial Notes.

Siloxicon Brick.—In our last volume, page 445, we referred to the formation of the Acheson Siloxicon Articles Co. According to a recent report in "The Cataract Journal," of Niagara Falls, the new plant of this company, on Buffalo Avenue, near the city, is now nearing completion. The Niagara Falls Power Co. has already obtained permission from the Common Council to string the new line to supply power to the Acheson Siloxicon Articles Co. Mr. E. G. Acheson expects to inaugurate at once "experiments at the new plant in the making of brick by the new process. Just how many hands will be employed is conjectural at this time. Early in spring the plant will be opened full-blast, and will give employment to a large number." Concerning the manufacture and the properties of siloxicon see our Vol. I., pages 287 and 373, and Vol. II., page 442.

Carbon Exhibit.—The National Carbon Co., of Cleveland, Ohio, had an interesting exhibit at the recent Electrical Show in New York, covering the complete line of primary batteries and carbon products. The new Columbia igniter cell for automobiles, the Stand By, Globe, Laclede, New Century, Hercules, Solar, Ravenna and Columbia signal dry cells, and the Trogan and National Fuller wet cells were on exhibition, as well as flash lights, carbon brushes, arc-light carbons, carbon electrodes, specialties, etc. The exhibit was in charge of Mr. A. E. Carrier and Mr. A. C. Henry.

Balances.—We have received from Messrs. Voland & Sons, New Rochelle, N. Y., their illustrated catalogue E on balances and weights of precision. The catalogue gives illustrated descriptions of assay balances, analytical balances, bullion balances, balances for scientific use, diamond balances, jewelers' balances, prescription balances, pulp balances, riders and all different kinds of weights. The new factory of Messrs. Voland & Sons, in New Rochelle, has been equipped in the best and modern way.

Bulletins No. 1046 and 1047 of the **Allis-Chalmers Co.**, electrical department, contain illustrated descriptions of Bullock multipolar motors and generators and of Bullock oil-insulated transformers.

Thermit.—Mr. E. Stütz' recent Franklin Institute paper on thermit practice in America, which was published in abstract on page 430 of our last issue, has now appeared in full in the December issue of the "Journal of the Franklin Institute," and has also been issued in nicely illustrated pamphlet form by the Goldschmidt Thermit Co., of New York.

Electric Ovens.—A recent invention of Prof. Morse and Dr. Frazer, of Johns Hopkins University—a graphite electric stove—furnishes an excellent heater for drying and constant-temperature ovens and baths. A particularly valuable feature of their method is that the graphite mixture may be applied to any desired shape and adapted to any safe voltage, and so the necessary heat for the oven is generated and used efficiently. Prof. Morse finds that several electric ovens in nearly continuous use in his laboratory are operated at a cost actually less than the same would cost with gas heating. The International Instrument Co., of Cambridge, Mass., manufacture them.

Crucible Melting Furnace.—The Monarch Engineering & Mfg. Co., of Baltimore, Md., have lately increased their plant facilities, in order to be able to fill promptly the rapidly increasing orders from foundrymen in this country and abroad for the Steele-Harvey crucible melting furnace, using fuel oil and air by either compressor or low-pressure blower. The crucible is not removed in the pouring of the metal, thereby extending the life of the same. There are no ashes or loss of metal in the pit. The furnace is specially used for melting aluminium, platinum, phosphor bronze, copper, tin and brass foundry mixtures, and strongly appeals to the brass foundryman, since the old style crucible is still used, but under modern methods. The capacities range from 120 to 1,200 pounds per heat.

Electric Traction in Mines.—The Westinghouse Electric & Mfg. Co. are doing a large business in equipping mines with electric locomotives, to replace the older forms of haulage, whether animal or mechanical. Electric mine haulage, considered from either the points of efficiency or economy, has so many advantages, as compared to the older practice, that the time is not far distant when any

other method of mine haulage will be the exception. A recent contract closed by the Westinghouse Co. is one with the Newport Mining Co., who have decided to equip their mines, at Ironton, Mich., with both surface and underground electric haulage. They will use electric locomotives the year around in the various levels underground for bringing the ore to the bottom of the shaft, and after the transportation season has closed will use electric locomotives on the surface for hauling ore from the top of the shaft to the various stock piles for storage. For these purposes they have ordered six 4-ton Westinghouse mine locomotives. Electrical apparatus for the equipment of the necessary power station will also be provided by the Westinghouse Co., consisting of a 150-kw., 250-volt generator, direct connected to a Corliss engine of 130 r. p. m., and a three-panel switchboard, besides other auxiliary apparatus.

Steam Turbines.—The success of the steam turbine makes it clear that with its aid steam power will be able to hold its own satisfactorily in many localities in competition with gas and water-power. The recent starting up of a steam turbine at the Washington Street power house of the Utica Gas & Electric Co., in Utica, N. Y., calls attention to the fact that this is the first turbine to be put into operation by the Allis-Chalmers Co., who have recently entered the steam turbine field. In doing so, the Allis-Chalmers Co. has effected an alliance with the Turbine Advisory Syndicate, of England, has made more recently an agreement which Hon. Charles A. Parsons for interchange of data, thereby giving to the Allis-Chalmers Co. the benefit of the vast experience of Mr. Parsons, the original inventor of this type of turbine, and to whose engineering ability and indomitable energy the evolution and present state of perfection of the successful steam turbine are principally due. We will publish a description of the Allis-Chalmers steam turbines in one of our next issues.

Steam Turbines as Reserve Power in Water Transmission Systems.—The Missouri River Power Transmission Co., operating in the vicinity of Helena, Mont., and notable as being one of the highest voltage transmissions in the world, has begun the erection of a steam turbine power plant, to operate as a reserve to their present water-power plant. A large part of the output of the Missouri River system is transmitted to the city of Butte and the Anaconda district mining properties, and the service has grown to such an extent as to warrant the erection of a reserve plant as a protection against serious fluctuations in the available water power. Turbines of the Westinghouse-Parsons type will be installed, the initial equipment consisting of two units of 2,000 kw. capacity each, operating at 1,200 r. p. m., with 150 pounds steam pressure, 28-inch vacuum, 100° superheat. They will be capable of delivering continuous overload of at least 50 per cent condensing, or full load without the assistance of a condenser. The generators will be of the revolving field type, and completely enclosed, with forced ventilation. This feature will entirely eliminate the peculiar hum of the high-speed turbine generator of the open type. The generators will operate at 1,200 r. p. m., and deliver 60-cycle, three-phase current at 2,400 volts. The motor-generator exciting and complete switchboard equipment accompanies the turbine plant. The Westinghouse Machine Co., builders of the turbines, will also equip the boiler plant with their mechanical stokers.

Gas Engines.—The De La Vergne Machine Co., of New York, which has recently completed its contract for 40,000 hp. of Koerting two-cycle, double-acting gas engines, of which 32,000 hp. is employed for driving blowing engines, and 8,000 hp. for driving direct current and polyphase alternating-current generators, have recently been given a contract for three 500-hp. Koerting gas engines, to be direct connected to 325-kw., 550-volt direct-current Crocker-Wheeler Generators for the Boston Elevated Company. These engines will be put in operation about Jan. 1, 1906. Owing to the rapidly increasing Southern business of the past year the De La Vergne Machine Co. has established a branch agency at Atlanta, Ga. This agency is to cover the States of North Carolina, South Carolina, Alabama, Florida and Georgia, and will handle business connected with the three lines of machinery manufactured by the De La Vergne Machine Co., viz.: refrigerating and ice-making machinery, "Hornsby-Akroyd" oil engines and Koerting gas engines. Their representative will be Mr. W. M. Hargreaves, and the office will be located at 510 Candler Building.

Electricity in the Cement Industry.—Cement is divided into two classes—slag and natural cement. In the manufacture of natural cement the rock is taken from the quarry or mines and burnt in a kiln. It is then run through a conical crusher, or between rolls and ground into a powder, after which it is conveyed to screens, which separate the cement which is fine enough to be packed. The coarser particles then go to fine grinding machines. Considerable power is required in these cement plants, and electricity is coming into general use. Either the alternating or direct-current system is adapted to this work, the choice depending on local conditions. The plant of the Iola Portland Cement Works, at Dallas, Tex., is equipped with Westinghouse type-S direct-current motors, and a contract just closed with the Santa Cruz Portland Cement Co., San Francisco, Cal., gives a good idea of the size of some of these plants. This order calls for one 800-hp. type-C motor, ten 250-hp., fifteen 150-hp., one 75-hp. and one 30-hp. type-CCL motors. These are all alternating-current motors of the induction type, and aggregate a total of 5,655 hp.

Storage Battery Exhibit.—At the recent Madison Square Garden Electrical Show, in New York City, the General Storage Battery Co. had an interesting exhibit of Bijur "high-duty" batteries and accessories of storage battery practice. Of special interest among the exhibits of this company were a charging booster and a constant-current booster. The charging booster consists of a constant-speed motor, driving a separately excited generator. When charging a storage battery, the armature of the separately excited generator is connected in series with the station bus-bars, and the combined voltage of the two sends current into the battery. As the battery charge proceeds its voltage increases, the excitation of the separately excited machine is increased accordingly, to maintain the charging current to the battery. The constant-current booster also consists of a constant-speed motor driving a separately excited generator. The excitation of this generator is automatically varied, in order to permit only a constant current to pass from the armature. The armature of the generator is connected to the terminals of a single storage cell, and at all times passes a current of constant value to this cell, regardless of the work being done in the circuit from the battery. The field winding of the generator consists of a single standard 110-volt winding, the exciting current in this winding being automatically varied by means of the Bijur regulator. The operation of fluctuating loads, such as in the operation of elevators, hoists, etc., was neatly illustrated on a miniature scale by some exhibits, in which violently fluctuating currents, produced by closing and opening an electric switch, were absorbed by a storage battery, operating in conjunction with a booster which fed a practically steady current to the battery of an average value equal to the amount of the violent fluctuations. The Bijur "high-duty" battery, which is built by

the General Storage Battery Co., was described at length in our Vol. III., page 203. The exhibit was in charge of the office force of the General Storage Battery Co., presided over by General Sales Manager J. B. Cowen. The General Storage Battery Co., whose factory is located at Boonton, N. J., has recently opened branch offices at the following addresses: Chicago, 111, 135 Adams Street; Cleveland, Ohio, 1234 Williamson Building; Washington, D. C., Commercial Bank Building.

Personal.

Mr. Isedore S. Prenner, E. E., attorney and counsellor has taken new offices at 1108 Betts Building, Philadelphia, where he will continue his practice as consulting engineer and electrochemist.

Mr. R. J. Truax has returned to Deadwood, S. D., from Cleveland, Ohio, where he attended the stockholders' meeting of the American Tungsten Co. A hoisting plant and camp buildings are now being erected on the tungsten property near Deadwood.

Mr. Edward Taylor, the distinguished inventor of a continuous electric furnace process for the manufacture of carbon bisulphide, sailed for Europe on Dec. 9. Mr. Taylor will attend the Congress of Applied Chemistry in Rome.

Dr. N. Monroe Hopkins has been appointed chief electrical engineer of the Bureau of Docks and Yards of the Navy Department in Washington. The office is a new one, which became necessary by reason of the ever-growing use of electricity in the navy yards and stations. Dr. Hopkins is a member of the firm of Monroe, Hall & Hopkins, chemists, assayers and electrical engineers, of Washington, and has held for several years the chair of electrochemistry at George Washington University. A handsome treatise from his pen on experimental electrochemistry has recently been issued (see our Vol., III., p. 477). Dr. Hopkins has a host of friends among electrochemists and electrical engineers, and many members of the American Electrochemical Society remember with pleasure the good services he rendered them as the very cordial and obliging chairman of the committee on entertainments at the society's Washington meeting in 1904.

Digest of U. S. Patents.

Compiled by Byrnes & Townsend, Patent Lawyers, National Union Building, Washington, D. C.

Treatment of Carbon and Production of Graphite.

No. 572,472, Dec. 1, 1896, Hamilton Y. Castner. London, England.

Produces a species of graphitic carbon by subjecting gas-retort or other carbon to the intense heating action attained by the passage of an electric current through it; *e. g.*, makes an electrode 18 inches long and 1 inch square, attaches to each end a carbon terminal of much larger diameter, covers the whole with powdered charcoal and passes a current of 500 amps. for a few minutes. The product has decreased density and increased conductivity, and is suitable for electrolytic anodes.

No. 617,979, Jan. 17, 1899, E. G. Acheson, Buffalo, N. Y.

Produces shaped articles consisting in whole or in part of graphite, for example, electric generator and motor brushes, pencils and crayons, crucibles and stove polish, by mixing powdered amorphous carbon, such as coke, charcoal or lampblack, with an elemental substance capable of combining with carbon, or with an oxide or salt of such substance, reducible by carbon, such as iron sulphate or peroxide, iron filings or silica, adding a binder, such as sugar, molasses, tar or pitch, shaping and electrically heating to a high temperature. The molded articles are preferably heated by placing them in a cylindrical or oblong bed of fine carbon, surrounded by a thick layer of granular, amorphous carborundum, and passing an electric current through the bed, serving as a resistance conductor. With a furnace having electrodes 16 feet apart and a carbon bed 20 inches in diameter, the starting current may be 300 amps. at 150 volts, increasing to 7,000 amps. at 100 volts. For motor brushes, the charge may consist of a mixture of powdered coke or charcoal 99 parts, and iron oxide 3 parts. The production of graphite is considered to be due to the successive production and decomposition of a carbide, the added base first combining with carbon and then being driven off as the temperature rises, to recombine with other carbon, until it finally escapes. It may be advisable to leave a portion of the amorphous carbon unconverted, to make the article stronger.

No. 618,704, Jan. 31, 1899, Hiram S. Maxim, London, England.

Produces a hard crystalline material resembling diamond, by heating a mixture of liquid or solid carbon dioxide and gasoline in an electric arc. The carbon in contact with or contiguous to the electrodes is converted into a species of diamond scale. It may be necessary to continue the high temperature for a long time, to allow the carbon to crystallize. By having only enough carbon to convert the carbon dioxide into carbon monoxide, with a little free hydrocarbon remaining, "the crystallization may take place from the residuum of gases." The product is used for the manufacture of lamp filaments. The electric furnace is a massive vessel of steel, lined with silica or magnesia brick, or with a metal tube having a spiral cooling pipe and closed at the ends by screw stoppers, through which pass the water-cooled holders of the carbon-rod electrodes.

No. 645,285, March 13, 1900, E. G. Acheson, Buffalo, N. Y.

Produces graphite by electrically heating a carbonaceous material, naturally containing distributed impurities which will progressively convert the carbon into a carbide: for example, anthracite coal containing 5.783 per cent of ash, consisting largely of silica, alumina and iron oxide, or lignite, peat, non-caking coals and some kinds of wood or charcoal. The charge is placed around the core of a resistance furnace, such as that used for the manufacture of carborundum, preferably a core of solid or loose graphite of reduced diameter. As the material is heated carbide, or carbides, for example, of silicon or iron, are progressively formed and decomposed, and the carbon is thus gradually converted into graphite before the final volatilization and escape of the impurities.

No. 702,758, June 17, 1902, E. G. Acheson, Buffalo, N. Y.

Produces graphite electrodes, motor and generator brushes, battery carbons, etc., by molding the articles of a mixture of carbon and impurities which will convert it into graphite, and placing the articles in a resistance furnace, transverse to the path of the current. The furnace may have a length of 30 feet and a width, for articles 30 inches long, of 52 inches. The base and walls are made of firebrick, the bottom being covered with a layer of silicon carbide. The articles are placed in a bed of finely-granular coke, and a thick layer of a mixture of ground coke and sand is placed between the bed and furnace walls and over the bed. The terminals, of amorphous carbon, may have a cross-section of 400 square inches. The articles, if plates, are arranged in spaced piles. When the articles are cylindrical they may be arranged transversely with their surfaces in contact, without interposed packing. The starting current may be 1,400 amps. at 210 volts, increasing for 5 hours to 3,600 amps. at 210 volts. The voltage is then lowered, the amperes increasing to 9,000 at 80 volts. The furnace is then cooled and the articles removed.